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## An Investigation of Individual Differences in Expected Utility Violations From the Dual Process Perspective

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INDIVIDUAL DIFFERENCES IN EXPECTED UTILITY

Abstract

Individual differences in 5 different types of expected utility (EU) violations are investigated using thinking orientation, a construct of dual process theories, as the predictor variable. The effect on choice performance of increasing the relative access of one thinking system or the other is also explored. The key findings are: (a) EU violations are independent of rational thinking; (b) experiential thinking correlates positively with the impossibility effect and negatively with ambiguity aversion; (c) increasing access to both systems improves performance for all participants, except those high on both thinking dimensions; (d) greater deliberation does *not* lead to lower violations; (e) the common consequence effect and certainty effect are positively correlated and the impossibility effect and ambiguity aversion are negatively correlated; and (f) men are more rationally oriented while women are more experientially oriented, women violate EU more than men, and both sexes show maximum improvement when primed on their respective thinking orientations. Results show that individual differences from the dual process perspective can have predictive implications for decision making under risk. An elementary model of dual process thinking is also proposed.

Key words: individual differences, expected utility, dual process systems, probability weighting, ambiguity aversion, Allais paradox

# An Investigation of Individual Differences in Expected Utility Violations from the Dual Process Perspective

Expected utility (EU) (von Neumann & Morgenstern, 1944; Marschak, 1950; Herstein & Milnor, 1953) is the predominant normative model of individual decision making under risk. The literature often differentiates between risk, where probabilities of possible outcomes are objectively known, like the toss of a fair coin, and uncertainty, where the probabilities are not known, like the possibility of rain tomorrow. Subjective expected utility (SEU) is the normative counterpart of EU in the domain of uncertainty (Ramsey, 1931; Savage, 1954; Anscombe & Aumann, 1963). These theories take an axiomatic approach, where they state that if preferences obey a specific set of "appealing" axioms or primitives, then those preferences can be represented by the mathematical expectation of some utility function.

Several decades of empirical research, testing the descriptive validity of EU and SEU, have shown that these theories, with all their normative appeal, fail to describe the actual choice behavior of people. Significant proportions of experimental participants have been found to violate one or more of the axioms of EU. The interested reader can consult Camerer (1995) for a detailed exposition of experimental evidence on EU, SEU and other theories on individual decision making under risk and uncertainty. Several theories have been proposed over the years to account for the departures from EU (Kahneman & Tversky, 1979; Chew & MacCrimmon, 1979; Bell, 1982, 1985; Loomes & Sugden, 1982, 1986; Chew, 1989; Dekel, 1986; Gul, 1991; J. L. Becker & Sarin, 1987; Handa, 1977; Karmakar, 1978; Viscusi, 1989). Its descriptive failures notwithstanding,

EU has retained its stature as the predominant rational theory of choice and is widely used in finance, economics and decision theory.

It has been demonstrated that many people violate the dictates of EU in their choice decisions, but there has been considerable variation of individual performance. The purpose of this work is to take the level of analysis one level deeper and explore individual differences in EU violations from the perspective of dual process theories of reasoning in social psychology. Do different thinking dispositions lead to consistent individual differences in decision making under risk and uncertainty? Specifically, the question explored is whether different thinking styles influence violations of rational choice at the level of the individual decision maker, rational choice being synonymous with EU compliance in this paper. In addition, several conditions that may affect compliance with EU through their influence on the use of one thinking style or another is explored. Aside from linking different thinking styles to risky choice behavior, this approach has obvious prescriptive implications as situations found to improve rational choice performance could then be implemented prior to decision making under conditions of risk and uncertainty. In addition, whether people violating one aspect of EU are more or less likely to violate another aspect of EU and whether there are gender differences in EU violations are explored. A detailed exposition of the research questions explored is provided in the *Research Questions* section.

Individual differences in EU adherence are explored from the perspective of dual process theories of reasoning. According to dual process theories, there are two fundamentally different ways of processing information, one variously labeled as intuitive, automatic, natural, narrative, and experiential, and the other analytical, verbal,

deliberative, and rational. Stanovich and West (2000) refer to the former system collectively as "system 1" and the latter collectively as "system 2." Psychological research on decision making has increasingly demonstrated that dual process models are more successful in explaining behavior than unitary models in a wide variety of settings (Chaiken & Trope, 1999; Kahneman, 2003; Epstein, 2003; Sanfey, Loewenstein, McClure, and Cohen, 2006; Hogarth 2001). There is also increasing evidence of multiple separable neural systems in the brain that contribute to decision making and behavior from the neuroscience literature (LeDoux, 1996; Sanfey, et al., 2006; A. R. Damasio, 1994, Berridge, 1995). Economics, too, is being increasingly influenced by a multiple systems approach to decision making (Loewenstein & Donoghue, 2004; Bracha, 2004; Bernheim & Rangel, 2004).

There are several dual process theories, many of which have been propounded to explain findings in specific areas of social psychology such as attitude formation, social cognition and motivation (Sloman, 1996; E. R. Smith & DeCoster, 2000; Strack & Deustch, 2004; Hogarth, 2005). There is also considerable overlap in the content and structure of the existing dual process theories (see Chaiken & Trope, 1999, for a comprehensive review of the field). The specific dual process theory used in this work is the cognitive-experiential self theory (CEST) (Epstein, 1973, 1994). This theory is arguably the most developed of the dual process theories and provides the richest conceptual descriptions of the two systems. It is general in the sense that it incorporates several other dual process theories, and most importantly provides us with well developed and established experimental measures that can be used to classify people into different thinking styles. The main aspects of the theory are summarized in the next section.

At an informal level, conventional wisdom suggests that individuals who are analytically predisposed in their thinking style should be less likely to violate EU than those who are not. Indeed, if EU being a normative theory, models the decision making of an infinitely rational and intelligent person, then people who are closer to this idealistic norm should violate EU significantly less often than those who are farther away. This follows directly from the axiomatic foundations of the theory since the axioms are considered to be rational primitives agreed upon by rational and intelligent individuals. Some recent economic models based on dual process systems (Loewenstein & Donoghue, 2004; Bracha, 2004) assume that EU is not only normative but also descriptive of information processing within the rational system. The source of all violations of EU resides in the experiential system. This paper raises doubts about the validity of this assumption.

The topic of individual differences in thinking tasks has a vast existing literature. Researchers have explored systematic correlations between responses to various decision tasks (for e.g., Wason's selection task, syllogistic reasoning, base-rate neglect, covariance detection, hypothesis testing, outcome bias, knowledge calibration, hindsight bias, framing effects, conjunction effects, honouring sunk costs, Newcomb's paradox, prisoner's dilemma, ratio bias, intertemporal choice, and risk preferences) and a variety of measures of individual cognitive ability, thinking dispositions, and other personality characteristics. Notably, thinking dispositions are able to predict individual differences in a variety of thinking tasks over and above cognitive ability (Stanovich & West, 1998; Cacioppo & Petty, 1982; S. M. Smith & Levin, 1996).

The structure of the paper is as follows. The next section summarizes the dual process theory, CEST, and provides a sketch of the EU violations investigated in this paper. This is followed by an exposition of the research questions explored, the experimental methodology, the experimental findings with discussions and finally the conclusion.

## Background Literature

### *CEST*

The paradigm of individuals as information processors has dominated the theoretical perspective of human decision making for over half a century. In the late 1950s, it was suggested that the brain can be modeled as a control system following a set of logical rules (Newell, Shaw & Simon, 1956). Beginning in the early 1970s, Amos Tversky and Daniel Kahneman investigated a wide range of errors and biases in human choice and judgment and discovered a number of heuristics or cognitive short cuts that people employed systematically in their decision making tasks (Tversky & Kahneman, 1971, 1974; Kahneman & Tversky, 1982). This heuristics and biases literature assumes a single information processing system including rational processing and a variety of unrelated constructs serving as simplifying heuristics. A new paradigm that has emerged in the last couple of decades is the existence of two fundamentally different information processing modes, encapsulated in several dual process models. The cognitive experiential self theory (Epstein, 1973, 1994) is one of the early models in this genre, which is compatible with many other theories including psychodynamic and learning theories and modern cognitive views on information processing.

CEST is a broadly integrative theory of personality which posits that humans operate by two fundamental information processing systems, a rational system and an experiential system. These systems operate in parallel and are interactive. Note "that the word 'rational' used in the rational system refers to a set of analytical principles and has no implications with respect to the reasonableness of behavior" (Epstein, 2003, p. 159).

Epstein, Pacini, Denes-Raj, and Heier (1996) describe CEST as the following:

> According to CEST, the rational system operates primarily at the conscious level and is intentional, analytic, primarily verbal, and relatively affect free. The experiential system is assumed to be automatic, preconscious, holistic, associationistic, primarily nonverbal, and intimately associated with affect. Heuristic processing represents the natural mode of the experiential system (Epstein, Lipson, Holstein, & Huh, 1992). . . . Behavior and conscious thought are a joint function of the two systems. The systems normally engage in seamless, integrated interactions, but they sometimes conflict, experienced as a struggle between feelings and thoughts (e.g., Denes-Raj & Epstein, 1994). The degree of relative dominance of either system in particular situations is determined by various parameters, including individual differences in preference for relying on one system more than the other, the degree to which the situation is associated with a customary way of responding (e.g., mathematical problems are primarily responded to in the mode of the rational system and interpersonal problems in the mode of the experiential system), the degree of emotional involvement, which is directly associated with degree of experiential dominance, and repeated amounts of relevant experience, or "proceduralization" (Anderson, 1982), which also

> favors experiential processing. With its long evolutionary history, experiential processing is often adaptive, but it is ill-suited for solving problems that require logical analysis and an understanding of abstract relations. (p. 391)

Epstein and his colleagues have developed the Rational-Experiential Inventory (REI) to measure different thinking predispositions (Epstein, et al., 1996). The REI is discussed in further detail in the *Method* section. Listed below are a few additional key points that describe the two systems as envisioned in CEST (see Epstein (2003) for a detailed review and experimental evidence):

1. Neither system is superior to the other. Each has certain advantages and limitations.

2. Interaction between the two systems occurs simultaneously as well as sequentially.

3. In most situations, the automatic, less effortful and rapid processing of the experiential system can bias subsequent processing in the rational system.

4. The rational system, being slower, is in a position to correct the spontaneous and impulsive thoughts from the experiential system.

5. The two systems can conflict with each other, where the experiential system can override the rational system even when subjects know the appropriate rational response, or there may be a compromise between the two systems (Denes-Raj and Epstein, 1994).

6. The prevalence of irrational thinking in humans can be attributed, in large part, to the influence of their automatic preconscious experiential processing on their conscious analytical thinking.

7. However, studies show that, under many circumstances, the experiential system is more effective at solving problems. Also, the rational system can interfere with the efficient functioning of the experiential system, resulting in poorer judgments (Epstein, Denes-Raj, & Pacini, 1995, Lewicki, Hill, & Czyzewska, 1992; Wilson & Schooler, 1991).

8. Priming intuitive knowledge in the experiential system can facilitate the solution to problems that people are unable to solve intellectually without such priming.

9. An unintentional way in which the rational system can influence the experiential system is through repetition of thoughts or behaviour, which then becomes habitualized with the control shifting from the rational to the experiential system (E. R. Smith & DeCoster, 2000).

10. Since the experiential system is associated with affect, it is experienced as more compelling than dispassionate logical thinking.

11. Emotional arousal and relevant experience shift the balance of influence towards the experiential system.

12. Rational and experiential processing scales, as measured by REI, are independent.

13. The intelligence of the experiential system is independent of the intelligence of the rational system and is more strongly associated with a variety of indexes of success in living than the intelligence of the rational system.

*Violations of Expected Utility*

Expected utility theory states that if preferences obey a particular set of axioms, the crucial ones being ordering, continuity and independence, then those preferences can

be represented by the expectation of some utility function (Neumann & Morgenstern, 1944). Informally, ordering requires that the preferences are complete and transitive, continuity guarantees the absence of open spaces in indifference curves, and independence requires that if two gambles have one or more common outcomes, then these common outcomes should be disregarded in a choice between the two gambles. Hence, for a discrete lottery $L$ with multiple outcomes $x_i$, each occurring with probability $p_i$, the expected utility of the lottery is given by the following functional form:

$$U(L) = \sum_i p_i u(x_i)$$

In subjective expected utility (Ramsey, 1931; Savage, 1954), people choose from among acts having different consequences for various uncertain states of nature. If preferences obey certain axioms similar to those in EU, then preferences among the acts can be represented by the expected utility of consequences weighted by the subjective probabilities of the uncertain states. Anscombe and Aumann (1963) combined EU and SEU by allowing both objective and subjective probabilities.

There is a long history of empirical investigation into the descriptive validity of expected utility. In this section I shall briefly summarize the key evidence of the EU violations investigated in this paper. The reader can refer to Camerer (1995) and the references therein for an in depth coverage of the topic.

*Common consequence effect (Allais paradox).* The most famous example of the violation of the common consequence axiom is the Allais paradox. Respondents choose between lotteries $L_1$ and $L_2$, where $L_1$ is a sure gain of 1 million francs and $L_2$ gives 5 million francs with probability 0.10, 1 million francs with probability 0.89 and 0 with probability 0.01. They also choose between lotteries $G_1$ and $G_2$, where $G_1$ gives 1 million

francs with probability 0.11 and 0 otherwise, and $G_2$ gives 5 million francs with probability 0.10 and 0 otherwise. The common choice pattern of $L_1$ over $L_2$ and $G_2$ over $G_1$ can be shown to violate the common consequence axiom. A choice pattern of $L_1$ and $G_1$ or $L_2$ and $G_2$ is required for consistency with EU.

Several instances of common consequence violations have been recorded over the years, for example, MacCrimmon (1965), Morrison (1967), Slovic and Tversky(1974), Moskowitz (1974), MacCrimmon and Larsson (1979) and Chew and Waller (1986). In summary, it has been found that the extent of violations depends on the outcomes and probabilities chosen for the lotteries and varies mostly between 30% and 60%.

*Common ratio effect*. In the common ration effect, due to Allais (1953), respondents choose between lotteries $L_1$ and $L_2$, where $L_1$ is a sure gain of 1 million francs and $L_2$ gives 5 million francs with probability 0.80 and 0 otherwise. They also choose between lotteries $G_1$ and $G_2$, where $G_1$ gives 1 million francs with probability 0.05 and 0 otherwise, and $G_2$ gives 5 million francs with probability 0.04 and 0 otherwise. Note that the ratio of probabilities in $L_1$ and $L_2$ is the same as in lotteries $G_1$ and $G_2$. It can be shown easily that the frequent choice of $L_1$ over $L_2$ and $G_2$ over $G_1$ constitutes a violation of EU. MacCrimmon and Larsson (1979), Chew and Waller (1986) and Kahneman and Tversky (1979) are examples of empirical investigation into the common ratio effect.

*Probability weighting*. That people do not treat probabilities linearly was shown early on by Preston and Baratta (1948), Griffith (1949), Attneave (1953) and Yaari (1965). It was formally modeled in prospect theory by Kahneman and Tversky (1979). The current view is that probability is weighted non-linearly according to an inverse S-

shaped weighting function which is concave for low probabilities and convex for mid and high probabilities (Camerer & Ho, 1994; Hartinger, 1999; Tversky & Kahneman, 1992; Wu & Gonzalez, 1996; Gonzalez & Wu, 1999). Also, sensitivity to changes in probability is markedly higher at the end points, 0 and 1, than in the middle range away from certainty and impossibility. This implies that low probabilities, close to 0 are over weighted and high probabilities, close to 1, are under weighted. Note that EU assumes that probabilities are weighted linearly. Hence, non-linear weighting of probabilities constitutes anomalous behavior in the form of the "impossibility effect," resulting from the overweighting of low probabilities, and the "certainty effect," resulting from the underweighting of high probabilities. Individual differences in both these effects are investigated in this paper.

*Ambiguity aversion.* The best known violation of SEU is the Ellsberg paradox (Ellsberg, 1961), which shows inconsistency with the sure-thing principle, the SEU counterpart of the common consequence axiom. The classical problem consists of an urn containing 30 red balls and 60 yellow and black balls in an unknown proportion, and hence ambiguous. Participants choose between acts $X$ and $Y$, where $X$ gives a reward W if a ball drawn randomly from the urn is red and 0 otherwise, while act $Y$ gives a reward W if a black ball is drawn. They also choose between acts $X'$ and $Y'$, where $X'$ gives a reward W if a ball drawn randomly from the urn is either red or yellow and 0 otherwise, while act $Y'$ gives a reward W if a black or yellow ball is drawn. The frequent choice is $X$ over $Y$ and $Y'$ over $X'$, showing that people prefer less ambiguous acts even though it is a violation of the sure-thing principle.

This problem and various variants have shown that ambiguity aversion is a robust phenomenon and people are immune to written arguments against their inconsistent choices (Slovic & Tversky, 1974) and are even willing to pay relatively large premiums (10-20% of expected value) to avoid ambiguity (S. W. Becker & Brownson, 1964; MacCrimmon & Larsson, 1979; Curley & Yates, 1989; Bernasconi & Loomes, 1992).

## Research Questions

This section lays out the research questions this study addresses. In all the different treatments in this experiment, the REI questionnaire was administered to classify the participant pool into different thinking dispositions and their performance on a series of choice questions testing different aspects of EU, as mentioned above, was recorded. Five different violations of EU were tested, (a) the common ratio effect, (b) the common consequence effect, (c) the impossibility effect, (d) the certainty effect, and (e) ambiguity aversion. The details of the experiment design and the questionnaires used are discussed in the next section. There is limited theory and empirical evidence directly addressing the link between thinking styles and individual decision making under risk and uncertainty. Since learnings from related literature provide mixed evidence, all research questions are treated as empirical questions.

EU is considered to be a rational theory of choice. Here rationality stems from the axioms on which the theory is based and which are deemed to be appealing to any logical and analytical mind. These axioms require that preferences and beliefs be coherent. It seems natural to expect that people with higher need for cognition or an analytical thinking disposition would be more consistent with their beliefs and preferences and hence more compliant with the demands of the EU calculus. There is some evidence in

the reasoning and judgment literature that links higher system 2 disposition to greater normative responses in tasks such as recognizing the relevance of base rates in likelihood judgments, recognizing the inappropriateness of honoring sunk costs and susceptibility to framing effects (Stanovich & West, 1999; Shiloh, Salton, & Sharabi, 2002; S. M. Smith & Levin, 1996). On the other hand, the need for cognition was not found to be predictive of performance in tasks such as hypothesis testing and the prisoners' dilemma (Stanovich & West, 1999).

It has been suggested that system 2 is sometimes used to supervise and provide checks and balances to the functioning of system 1, especially when the response of the two systems to a problem is in conflict. Hence, system 2 can step in for greater deliberation when required, thereby leading to superior decisions (Stanovich & West, 2000). However, there is also evidence showing that becoming more analytical can be detrimental to optimal decision making (Wilson & Schooler, 1991; Galotti, 1995; Wilson, et al., 1993). All instances of system 1 overrides need not be efficient. It is unclear how rational thinking orientation will affect EU compliance, bringing us to the first research question:

*1. How does rational thinking style influence EU violations?*

As mentioned above, the rational and experiential dimensions in CEST are orthogonal (Epstein, et al., 1996) and can be investigated independently. Also, the information processing in the experiential system is regarded to be heuristic in nature (Epstein, 2003; Stanovich & West, 2000; Kahneman, 2003) and it has been shown that heuristics can lead to non-normative decision making (Kahneman, Slovic, & Tversky, 1982). On the other hand, people with damage to the ventromedial pre-frontal cortex

region, the emotion processing centre of the brain, develop serious shortcomings in their personal and social decision making even though their rational thinking faculties seem intact (Bechara, H. Damasio, Tranel, & Anderson, 1998; A. R. Damasio, Tranel, & H. Damasio, 1990; A. R. Damasio, 1994; Eslinger & A. R. Damasio, 1985). Though evidence in the psychology literature and conventional wisdom seems to suggest that a higher experiential orientation will lead to higher rationality violations, evidence from brain research suggests that the process is much more complex. Emotion can be beneficial to decision making if it is integral to the task, but disruptive when it is unrelated. The "somatic marker hypothesis," a neuroanatomical and cognitive framework for decision making, implies that sound rational decision making depends on prior accurate emotional processing (Bechara & A. R. Damasio, 2005; A. R. Damasio, 1994; A. R. Damasio, Tranel, & H. Damasio, 1991). Since emotion is integral to experiential thinking as envisaged by CEST, it is unclear how this type of processing will influence EU violations. Also, Gigerenzer and Goldstein (1996), using simulations of human judgment, show that "fast and frugal" heuristics can outperform more rational models. Hence, the influence of experiential thinking on EU violations is posed as the next research question:

*2. How does experiential thinking style influence EU violations?*

How does influencing the access of the rational or experiential system affect the incidence of EU violations? This is investigated in four different ways. A rational priming task, consisting of quantitative problem solving, was used to increase access to the rational system and an experiential priming task, consisting of affect loaded questions, was used to increase access to the experiential system. A third manipulation asked the

participants to imagine themselves as agents of some other abstract entity like an organization or an individual while responding to the choice questions in the test questionnaire. The assumption here is that when the decision maker is not the beneficiary of the outcomes, the emotional involvement is less, thereby reducing the influence of the experiential system. In the fourth manipulation, the participants made choices under the influence of a cognitive load. It has been established that people have limited cognitive capacity. When this capacity is loaded, the relative use of the experiential system should increase. In related research, using a similar dual process paradigm, Baumeister and colleagues have shown that over-riding affective motivations require an exertion of effort by the rational system. This "willpower" is in limited supply and usage in one task makes it less available for another successive one (Baumeister and Vohs 2003). One way to operationalize cognitive load is to tax the working memory, which is the ability to store small amounts of information during cognitive processing, and has been used successfully by Shiv and Fedorikhin (1999) in a study linking cognitive load with self control. Hence, the rational priming and acting-as-agent manipulations increase the relative accessibility of the rational system, while the experiential priming and cognitive load manipulations increase the relative accessibility of the experiential system. Also, rational and experiential priming are direct manipulations, while the other two are indirect. Consistent with the previous two research questions, nothing specific can be predicted about shift, if any, in EU performance on increased use of the rational or experiential systems. Stated formally:

3. *What effect does increasing access to the rational system have on EU performance?*
4. *What effect does increasing access to the experiential system have on EU performance?*

Two worthwhile questions to investigate are how any improvement or worsening of EU performance due to the manipulations above is distributed across the different types of EU violations on one hand and different thinking styles on the other. Can some types of violations be improved upon more easily than others? Do people with different thinking styles respond differently to manipulations influencing accessibility of one system or the other? Knowledge of aspects of decision making that are more or less resistant to improvements have obvious prescriptive implications. In trying to improve decision making, it may be more efficient to invest in areas where people can improve more easily. Also, different prescriptive approaches may be desired for people with different thinking styles. The first step in this direction is to address the following questions:

5. *Do people with certain thinking styles respond more favorably to priming conditions than others?*

6. *Are certain types of EU violations more responsive to priming conditions than others?*

The reaction time of the participants in each of the test questions was recorded. CEST tells us that the rational system is deliberative, with slower processing and delayed action, while the experiential system is characterized by more rapid processing and immediate action (Epstein 2003). Rubinstein (2007) analyzes response times in virtual decision and game situations and suggests that "choices made instinctively, that is, on the basis of an emotional response, require less response time than choices that require the use of cognitive reasoning" (p. 1243). Hence, people using more time to make their choices are more likely to be using their rational system more than their experiential system. Does using more time to consider the choices help in rational decision making?

On one hand, reflective consideration of the choices could help correct impulsive biases, but on the other hand thinking too much about the reasons for making a choice could itself be responsible for introducing inconsistencies. "Analyzing reasons can focus people's attention on non-optimal criteria, causing them to base their subsequent choices on these criteria" (Wilson & Schooler, 1991, p. 181). A potential limitation of this reaction time study is the presence of noise in the data due to different reading and thinking speeds of the participants. Nonetheless, it may be worthwhile to get an answer, albeit unrefined, to the following question:

*7. Does using more time for decision making lead to lower EU violations?*

The individual differences research in reasoning and judgment shows significant correlations between performances in different tasks, i.e., a person responding normatively to one reasoning task is more likely to respond normatively to a different reasoning task (Stanovich & West, 2000). This analysis can be extended to the domain of choice under uncertainty as well. Is a person committing one type of EU violation more likely to commit other types of violations as well? In other words, is the population divided into EU "haves" and "have-nots"? This approach can also be used as an alternative route to test certain theoretical assertions or even as inputs for model building and theorizing. For example, the certainty effect arising from the underweighting of large probabilities is widely considered to be a plausible explanation for the violation of independence in the Allais paradox. If this were true, then we should expect a positive correlation between these two violations in this individual differences approach. Another example is in the area of probability weighting functions. As explained later, the one parameter probability weighting function (Kahneman & Tversky, 1992) predicts a

positive correlation between the incidence of the certainty effect and the impossibility effect, while the two parameter probability weighting model (Lattimore, Baker, & Witte, 1992) predicts no such correlation. Other correlations, if any, can potentially serve as pointers to a need for model building or enhancement, if they cannot be explained within the confines of the existing theory. Interestingly, a negative correlation was found between ambiguity aversion and the impossibility effect that has not been discussed in the literature before. The general research question attempting to address the issues raised above can be formulated as:

*8. How do the different types of EU violations correlate?*

Are women more intuitive and men more analytical? Are women more prone to rationality violations than men? These stereotypes have a long history in the popular literature and are almost an integral part of popular culture. It has been suggested that the female brain has less grey matter (central mass of nerve cells) and more white matter (filaments connecting nerve cells) than the male brain and is hardwired for understanding emotions whereas the male brain is more suited for organizing and building systems (Baron-Cohen, 2002). Gender differences seem to matter in the domain of decision making under risk and uncertainty (Byrnes, Miller, & Schafer, 1999). The broad findings are that women are more risk averse (Jianakoplos & Bernasek, 1998; Sunden & Surette 1998; Hershey & Schoemaker, 1980; Powell & Ansic, 1997; Barsky, Juster, Kimball, & Shapiro, 1997), more pessimistic and more insensitive to probabilities than men (Fehr-Duda, De Gennaro, & Schubert, 2006). However, there are important contextual variables like domain familiarity and social roles that play a mediating role in these findings (Levin, Snyder, & Chapman, 1988; Johnson & Powell 1994; Schubert, Brown, Gysler, &

Brachinger, 1999; Voelz, 1985; Radecki & Jaccard, 1996). Much less is known about gender differences in rationality violations. Only recently, Matsushita, Baldo, Martin, and Da Silva (2007) found that men violate the Allais paradox more than women.

In terms of thinking styles, Pacini and Epstein (1999), using the REI measure, found a significant gender effect in thinking styles, with men more likely than women to identify themselves as rationally capable, and women more likely than men to identify themselves as engaging in experiential processing and being good at it. The current study replicates this result, but this methodology cannot resolve the question of whether gender differences actually exist in thinking styles. This is due to the fact that there is a confounding between true differences in thinking styles and the expected differences possibly driven by existing gender based stereotypes. We can, however, explore the question of gender based differences in violations of EU. This paper extends the work of Matsushita, et al. (2007) to include other types of EU violations in addition to the Allais paradox. Also, the experiments reported here allow us to explore whether different treatments like priming and cognitive load have differential effects on men and women. Hence, our research question can be formulated as:

9. *Are there any gender based differences in thinking styles and EU violations? Does influencing access to the rational or the experiential system affect men and women differently?*

The next section provides details of the experiment design and is followed by the results.

## Method

### *Participants*

The participant pool consisted mainly of University of Paris students attending the Sorbonne campus. These were mainly undergraduate students from a wide variety of academic fields and most were not exposed to expected utility theory in the past. The age of the participants ranged between 19 and 26 years.

*Procedure*

Each participant answered a questionnaire in French, divided into multiple sections and administered via a computer interface. Each participant received a fixed payment of a movie coupon worth 7 Euros redeemable at the nearest movie theatre. There was an additional incentive payment in the cognitive load study which is described in the *Studies* subsection. Participants were recruited by professional recruiters from the nearby campus. They read and signed a consent form before starting the questionnaires and were debriefed individually once they finished.

The reaction time, defined as the time lapsed between the appearance of a question on the screen and the clicking of the "Next" icon to go to the next question, was recorded in milliseconds for each test question for every participant. The participants did not know that their reaction times were being recorded. Participants could not proceed to the next question without having selected the desired response to the current one, thus eliminating any problem of missing data. All participants using less than an average of 5 seconds per question were excluded from the final analysis as it was felt highly unlikely that participants could comprehend the questions and answer them in such a short span of time. The average time taken per question by all the participants in the studies was 19 seconds with a standard deviation of 7 seconds. The choice of 5 seconds, 2 standard deviations below the mean, was felt appropriate to filter out participants very likely to

have a very low level of motivation. This resulted in the exclusion of about 5% of the total participants from the final analysis.

*Sample Size and Power*

Input for appropriate sample sizes was taken from Cohen (1992, Table 2, p. 158). The $N$ for medium effect size at power = .80 and $a = .05$ for tests of mean difference and significant $r$ are listed as 64 and 85 respectively. While I made sure that the sample sizes in the studies reported here were all greater than 85, the actual sample sizes were constrained by budget and time considerations.

*Studies*

Table 1 summarizes the 6 studies reported in this paper.

*Base case (Study 1).* In this study 184 participants took the REI questionnaire followed by the EU test questionnaire. The average time criterion for response in the test questions resulted in the exclusion of data from 10 participants.

*Analytical priming (study 2).* In this manipulation, 119 participants took the REI questionnaire, followed by the analytical priming questionnaire and finally answered the EU test questions. The average time criterion resulted in the exclusion of data from 4 participants.

*Experiential priming (Study 3).* In the experiential priming manipulation, 165 participants took the REI questionnaire, followed by the experiential priming questionnaire and finally answered the test questions. The average time criterion resulted in the exclusion of data from 11 participants.

*Acting-as-agent (Study 4)*. In this manipulation, 180 participants took the REI questionnaire followed by a modified version of the test questions. The average time criterion resulted in the exclusion of data from 11 participants.

*Cognitive load (Study 5)*. In the cognitive load condition, 141 participants took the REI questionnaire, which was followed by the cognitive load manipulation before they finally answered the test questions. The average time criterion resulted in the exclusion of data from 10 participants. The cognitive load manipulation consisted of displaying a 9 digit number on the computer screen for 15 seconds. The participants were told that they would receive a gift (portable radio worth 2 euros) if they could recall the number correctly at the end of the experiment. Care was taken to make sure that the participants did not use any memory aid. As mentioned earlier, this manipulation is assumed to suppress accessibility to the rational system thereby increasing relative accessibility to the experiential system.

*Decision rules (Study 6)*. This study adopts a different approach to address some of the research questions investigated by the previous 5 studies. In Studies 1 to 5, compliance with the rules of EU was inferred from the choices the participants made. In this study, agreement with different decision making aspects was directly solicited from the participants. The results of this study supplement the findings of the previous studies by contributing to the robustness of the results under different response conditions. In this study, 164 participants took the REI questionnaire followed by a questionnaire on decision rules.

*REI Questionnaire*

The Rational-Experiential Inventory is a 40 point self-report questionnaire, based on CEST, which measures the rational and experiential predisposition of an individual's thinking style (Pacini & Epstein, 1999). See Pacini and Epstein (1999), Epstein, et al. (1996), Pacini, Muir and Epstein (1998) and Rosenthal and Epstein (2000) for details of the development and validity of the scale and a comparison with other measures of personality and thinking styles. The rational (based on the Need for Cognition scale developed by Cacioppo and Petty (1982)) and experiential thinking scales (denoted by *R* and *E* respectively) are composed of two subscales each, Rational/Experiential Ability and Rational/Experiential Engagement, with the 40 items evenly distributed among the 4 subscales. According to Pacini and Epstein (1999):

> Rational Ability refers to reports of a high level of ability to think logically and analytically…. Rational Engagement refers to reliance on and enjoyment of thinking in an analytical, logical manner…. Experiential Ability refers to reports of a high level of ability with respect to one's intuitive impressions and feelings…. Experiential Engagement refers to reliance on and enjoyment of feelings and intuitions in making decisions. (p. 974)

The rational and experiential scales are obtained by simply summing the two respective subscales. In this study, a French version of the REI questionnaire was used, previously validated and used by de Stadelhofen, Rossier, and Rigozzi (2004).

Each question is in the form of a statement. Each participant evaluates every statement and indicates how true each statement is about himself or herself on a 5-point scale ranging from 1 (*completely false*) to 5 (*completely true*). The statements were

presented in a random order to the participants. Given below are examples of items from the questionnaire.

*Rational ability*

I am not a very analytical thinker.

I am much better at figuring things out logically than most people.

*Rational engagement*

I prefer complex problems to simple problems.

I try to avoid situations that require thinking in depth about something.

*Experiential ability*

I believe in trusting my hunches.

I trust my initial feelings about people.

*Experiential engagement*

I like to rely on my intuitive impressions.

I don't like situations in which I have to rely on intuition.

The correlation between rational thinking and experiential thinking in studies 1 to 6 was $r(907) = -.08$ which, in contrast to the insignificant correlations found in other studies (Epstein, 2003, and references therein), is significant at the 5% level. However, given the weak correlation in a large data set, the assumption of orthogonality between rational and experiential thinking is maintained in this paper. The internal consistency of the measures was satisfactory at $a = 0.85$ for rational thinking and $a = 0.88$ for experiential thinking.

Some of the analytical results in this paper are based on categorizing the participants into 4 segments based on whether they are high or low in rational and

experiential thinking. Hence, we have high rational-high experiential, high rational-low experiential, low rational-high experiential and low rational-low experiential thinkers. The demarcation boundaries are the median values of each dimension, which are 3.65 and 3.25 for the rational and experiential measures respectively. Hence, the high rational-high experiential category consists of those respondents who had a rational score of 3.65 or more and an experiential score of 3.25 or more. Other categories are similarly classified. The summary statistics of the different categories is provided in Table 2 and clearly shows that the category means are significantly well separated on the relevant dimension from the neighboring categories.

Similarly, the high and low rational categories and the high and low experiential categories are significantly separated in their relevant mean scores (Table 3). Hence, the High R group has a significantly higher rational score than the Low R group with very large effect size, $t$ = 25, $d$ = 2.56, but similar experiential scores; and the High E group has a significantly higher experiential score than the Low E group with very high effect size, $t$ = 36, $d$ = 2.64, but similar rational scores. This shows that the REI scores were sufficiently spread out for meaningful analysis of the test data.

*EU Test Questionnaire*

As mentioned earlier, the studies reported here tests for 5 different types of EU violations, (a) the common ratio effect, (b) the common consequence effect, (c) the impossibility effect, (d) the certainty effect and (e) ambiguity aversion. There were two tests of each type in the questionnaire. The questions were presented via a computer interface in a randomized order. The measure of EU violations is simply the total number of violations committed. The different types of violations have been known to occur with

different propensities in the literature, but it is not immediately clear whether one type of violation has more serious consequences than another. Hence, all types of violations are given the same weight in coming up with the measure of EU violations. The lower the score the more rational the person is from an EU perspective.

In order to make the lottery type questions less abstract and more relatable, some of them were described in terms of an investment. This was done as it was felt that introducing some neutral context around abstract lottery questions makes them less dry and boring for the participants. Similar contextual questions were used in Larsson and MacCrimmon (1979). In order to make sure that this did not have any effect on the response patterns, another version of the questionnaire containing the abstract versions of some of the contextual questions was administered to some of the participants. For example, the following contextualized pair of choice questions testing for the common consequence effect was used in the main questionnaire:

Question 1:

Imagine that you are considering investing in either business A or business B. After careful analysis, you conclude that if you invest in business A, there is a 20% chance of earning 20,000 EUR, 75 % chance of earning 10,000 EUR and 5% chance of earning nothing; whereas if you invest in business B you are sure to earn 10,000 EUR. Which business would you invest in? Please indicate your preference by clicking on the appropriate choice.

A: 20% chance of 20,000 EUR

75% chance of 10,000 EUR

5% chance of nothing

B: Sure earning of 10000 EUR

Question 2:

Imagine that you are considering investing in either business A or business B. After careful analysis, you conclude that if you invest in business A, there is a 20% chance of earning 20,000 Euros and 80% chance of earning nothing; whereas if you invest in business B, there is a 25% chance of earning 10,000 Euros and 75% chance of earning nothing. Which business would you invest in? Please indicate your preference by clicking on the appropriate choice.

A: 20% chance of 20,000 Euros

80% chance of nothing

B: 25% chance of 10,000 Euros

75% chance of nothing

Note that choice of A or B in both the choice questions above is required for consistency with EU. However, many people choose B in the first question and A in the second thus violating EU. The following abstract version was administered to some participants to test whether the context had an effect on the choice response:

Question 1a:

Consider that you are given the choice between option A and option B. Please indicate which option you would prefer by clicking on the appropriate choice.

A: 20% chance of 20,000 Euros

75% chance of 10,000 Euros

5% chance of nothing

B: Sure earning of 10,000 Euros

Question 2a:

Consider that you are given the choice between option A and option B. Please indicate which option you would prefer by clicking on the appropriate choice.

A: 20% chance of 20,000 Euros

80% chance of nothing

B: 25% chance of 10,000 Euros

75% chance of nothing

No significant differences were found in the responses between the two versions and hence the data was merged for further analysis. It is thus suggested that a neutral decision making context can be used in place of abstract lotteries in experimental settings, thereby reducing boredom for the participants especially in experiments consisting of a large number of lottery questions.

An example of a test of the common consequence effect is provided above. Given below are examples of questions used in the test questionnaire for the other effects.

*Common ratio effect*. This question is taken from Kahneman and Tversky (1979).

Question 1:

Imagine that you want to strike a business deal with either party A or party B. You estimate that if you strike a deal with party A, then you will surely make a profit of 3,000 Euros; but if you go with party B, then you have 80% chance of making 4,000 Euros and 20% chance of making nothing. Who would you prefer to deal with? Please indicate your preference by clicking on the appropriate choice.

A: Sure profit of 3,000 Euros

B: 80% chance of 4,000 Euros

20% chance of nothing

Question 2:

Imagine that you want to strike a business deal with either part A or party B. You estimate that if you strike a deal with party A, then you stand a 25% chance of making a profit of 3,000 Euros and 75% chance of making nothing; but if you go with party B, then you have 20% chance of making 4,000 Euros and 80% chance of making nothing. Who would you prefer to deal with? Please indicate your preference by clicking on the appropriate choice.

A: 25% chance of 3,000 Euros

75% chance of nothing

B: 20% chance of 4,000 Euros

80% chance of nothing

Choice of A or B in both the questions above is required for consistency with EU. However, many people choose A in the first question and B in the second thus violating EU.

*Impossibility effect*.

Imagine that you own a lottery ticket which gives you a 1 in 100 chance of winning 500 Euros (Option A below). Now suppose someone offers you 10 Euros for the lottery ticket (Option B below), would you be willing to sell your ticket at this price? Please indicate your decision by choosing either A or B below.

A: 1% chance of winning 500 Euros

99% chance of winning nothing

B: Ticket sale amount of 10 Euros

Note that choice B, the sure amount, is greater than the expected value of the lottery in choice A. Under EU, the choice of A would imply unrealistic risk seeking behavior. To illustrate, assume a utility function of the form $U(x) = x^a$. At zero initial wealth, choice A implies $a > 1.18$, which increases rapidly with wealth, reaching $a > 2.7$ at an initial wealth of only 500 Euros. Considering that EU implies near risk neutrality for small and medium size lotteries (Rabin, 2000), these levels of risk seeking attitudes are unrealistic. A choice of lottery A can be explained only through an overweighting of low probabilities, constituting the impossibility effect. Hence, choice of option A above is considered as a violation of EU.

*Certainty effect*

Imagine that you own a lottery ticket which gives you a 99 in 100 chance of winning 500 Euros (Option A below). Now suppose someone offers you 490 Euros for the lottery ticket (Option B below), would you be willing to sell your ticket at this price? Please indicate your decision by choosing either A or B below.

A: 99% chance of winning 500 Euros

1% chance of winning nothing

B: Ticket sale amount of 490 Euros

Note that choice B, the sure amount, is lower than the expected value of the lottery in choice A. Under EU, the choice of B would imply unrealistic risk averse behavior. As above, assume a utility function of the form $U(x) = x^a$. At zero initial wealth, choice B implies $a < 0.5$, which decreases rapidly with wealth, reaching

$a < 0.08$ at an initial wealth of only 100 Euros. Due to the same considerations as in the impossibility effect, these levels of risk averse attitudes are unrealistic. A choice of lottery B can be explained only through an underweighting of high probabilities, constituting the certainty effect. Hence, choice of option B above is considered as a violation of EU.

*Ambiguity aversion*. The classical Ellsberg paradox (Ellsberg 1961) was used.

Consider an urn containing 90 balls. You know there are 30 RED balls but you do not know the composition of the remaining 60 BLACK and YELLOW balls. One ball is to be drawn at random from the urn. Which would you prefer, A or B?

Question 1:

A: Receive 100 Euros if a RED ball is drawn

B: Receive 100 Euros if a BLACK ball is drawn

Question 2:

A: Receive 100 Euros if a RED or YELLOW ball is drawn

B: Receive 100 Euros if a BLACK or YELLOW ball is drawn

Choice of A or B in both the questions above is required for consistency with EU. However, many people choose A in the first question and B in the second, exhibiting ambiguity aversion and violating Savage's sure-thing principle (Savage, 1954) of SEU.

As mentioned above, in the common consequence, common ratio and ambiguity aversion type of questions, the people who violate consistency seem to do it mostly in one direction. Hence, in the Allais paradox example above, the violations can be expected to be dominated by the B and A choice pair for questions 1 and 2 respectively. Similarly, choice pair A and B should be more common in the violations of common ratio and the

Ellsberg paradox. The percentage of violations in the expected direction was 84% for the common consequence effect, 84% for the common ratio effect, and 89% for ambiguity aversion, all of which are significantly larger than 50%. Hence, this data gives confidence in the validity of the responses obtained in the experiment and shows that the violations of rationality is systematic and not merely the result of random response errors.

*Analytical Priming Questionnaire*

The analytical priming questionnaire consisted of 5 simple math questions which the participants were required to solve mentally. Similar priming has been used in Hsee & Rottenstreich (2004). An example is provided below:

Three shirts are on sale for 50% off of their original price of 12 Eur each. How much are the 3 shirts?

a) 36 Euros

b) 33 Euros

c) 18 Euros

d) 24 Euros

*Experiential Priming Questionnaire*

The experiential priming questionnaire consisted of 5 questions designed to evoke feelings about affect rich entities. An example is provided below:

When you hear the name "Nikolas Sarkozy," what do you feel? Please use a word or sentence to describe your predominant feeling.

*Acting-as-Agent Questionnaire*

The acting-as-agent questionnaire was the same as the EU test Questionnaire, except that the participants were asked to imagine that they were making the choice

decisions on behalf of some other abstract entity. The instructions used are provided below:

> This section explores individual decision making in an economic setting. The experimenters are trying to determine how people make choices among alternatives with uncertain outcomes, WHEN THEY ACT AS AGENTS OF ANOTHER PERSON OR ORGANIZATION. We have designed a simple choice experiment in which we shall ask you to make choices in a sequence of items, or decision making situations. IN EACH SITUATION IMAGINE THAT YOU ARE CHOOSING ON BEHALF SOME OTHER ENTITY. THE OUTCOMES OF THE DECISIONS WILL NOT ACCRUE TO YOU, BUT WILL ACCRUE TO THE ENTITY ON WHOSE BEHALF YOU ARE TAKING THE DECISION. Each item consists of two lotteries or bets and you need to indicate which one, between the two, you would recommend.

As an illustration, the modified version of question 1 from the common ratio effect is presented below:

> Imagine that a person wants to strike a business deal with either party A or party B. He estimates that if he strikes a deal with party A, then he will surely make a profit of 3,000 Euros; but if he goes with party B, then he has 80% chance of making 4,000 Euros and 20% chance of making nothing. He requests you to choose the party on his behalf. Which party would you recommend, A or B?
>
> A: Sure profit of 3,000 Euros
>
> B: 80% chance of 4,000 Euros
>
> 20% chance of nothing

As mentioned before, this manipulation is assumed to increase the relative accessibility of the rational system.

*Decision Rules Questionnaire*

In this questionnaire, rather than making choice decisions, the participants used a scale response to answer 6 questions which were presented in a random order. Question 1 directly addressed the issue "head versus heart" in decision making and is stated below:

Question 1:

In a choice between any 2 options, A & B, if A feels better but logical analysis tells you that B is better, then you should choose B. Please indicate to what extent you agree with the above rule.

Participants selected from 0 (*strongly disagree*) to 7 (*strongly agree*). There were 3 questions, questions 2 to 4, addressing the independence axiom and ambiguity aversion. The question on the independence axiom is stated below:

Question 2:

Consider the following example: Imagine that you have a choice between two options A & B. In option A there is a 50% chance of winning an I-pod and 50% chance of winning two tickets to the movies; while in option B there is a 50% chance of winning a DVD player and 50% chance of winning two tickets to the movies. These options are summarized below:

A: 50% chance of I-pod

50% chance of 2 movie tickets

B: 50% chance of DVD player

50 % chance of 2 movie tickets

Since the movie tickets are common to both options and have the same chance of occurrence, these should not be considered further in your choice decision. Hence you should choose between A and B based only on your preference between I-pod and DVD player. This can be generalized to the following rule: In a choice between 2 options, A & B, if each of them has one or more common outcomes having the same chances of occurrence, then these common outcomes should play no role in determining your choice. Please indicate to what extent you agree with the above rule.

Participants selected from 0 (*strongly disagree*) to 7 (*strongly agree*). Finally, there were two questions, questions 5 and 6 that addressed the impossibility and the certainty effect, with one question in the gain domain and the other in the loss domain. These questions were not presented as decision making rules as probability weighting is more a psychological phenomenon than a decision rule. The questions were designed on the assumption that overweighting of small probabilities can be given the interpretation of optimism or pessimism depending on whether the possible outcome is a gain or a loss. Higher overweighting should lead to reports of higher levels of optimism or pessimism. The two questions were:

Question 5:

Imagine that you are considering buying a lottery ticket which gives you a small chance (say less than 5%) of a large prize. Please indicate how optimistic you would be of winning the prize while making the purchase?

Question 6:

> Imagine that you are considering buying insurance which will cover you for theft of a valuable item you own. The chance of theft is very small (say less than 5%). Please indicate how pessimistic you would be of losing your valuable item while making the purchase?

Participants selected from 0 (*not optimistic at all*) to 7 (*very optimistic*) in both the questions.

*Note on Real Incentives*

In the experiments reported in this paper, the participants were paid a flat fee rather than on the basis of the choices they made. A common criticism is that behavior is less realistic without real incentives. However, this criticism seems to be largely unfounded, especially in the domain of EU violations. Many researchers have found no differences or only non-qualitative differences on comparing hypothetical choices with real choices. See Camerer (1995) and Camerer and Hogarth (1999) and references therein for a detailed survey and discussion on this issue. Camerer (1995) states the following:

> …choice over money gambles is *not* likely to be a domain in which effort will improve adherence to rational axioms. Subjects with well-formed preferences are likely to express them truthfully, whether they are paid or not. If their preferences are not well formed, it seems unlikely that subjects would be both sophisticated and lazy enough to make an expected utility calculation when they are paid, but not when choices are hypothetical. (p. 635)

In any case, we are only interested in relative levels of EU violations and the absence of real incentives should not have any impact. The next section presents and discusses the results.

## Results and Discussion

For the sake of clarity the research questions are restated below followed by the experimental results.

*How Does Rational Thinking Style Influence EU Violations?*

The correlation results between rationality scores from the REI and aggregate number of EU violations in the various studies is shown in Table 4. None of the correlations are significant and neither are there any directional consistency with two positive and three negative correlations with the aggregate rational score. This suggests that access to or use of rational or analytical thinking style does not influence compliance with EU. This result extends to the different types of EU violations as well shown in Table 5.

The only instances of marginal statistical significance at the 10% level are a negative correlation with the common ratio effect in the base case and a positive correlation with ambiguity aversion in the analytical priming condition and the consolidated participant pool. These, however, are weak correlations and the large majority of data suggests that rational thinking has no impact on EU violations. Interestingly, the data from the *Decision Rules* study, where participants used scale responses to express level of agreement with the rational coherence demanded by EU, also indicate insignificant correlations with rationality scores. The average score for responses to questions 2 to 6 served as a measure of agreement with the EU logic and

correlated insignificantly with rationality scores from the REI, $r$ (164) = .06. However, regarding question 1 in the same study, rational thinkers do agree more with the notion that logical analysis rather than feeling good about a choice option should dictate choice, $r$ (164) = .22, $p < .01$. Hence, if people who are more rationally oriented and who give more importance to logical thinking in the choice domain do not agree more with the logic of the EU calculus, then it raises philosophical questions about the status of EU as a rational theory of choice. A detailed discussion of this issue is beyond the scope of this paper.

It is interesting to compare the independence of rational thought orientation and normative responses in the domain of choice under uncertainty with findings in the individual differences literature on reasoning and judgment. There is mixed evidence of the effect of thinking orientation on framing effects with S. M. Smith and Levin (1996) reporting that higher need for cognition respondents were less susceptible to framing effects and Levin, Gaeth, Schreiber, and Lauriola (2002) and Leboeuf and Shafir (2003) finding no such correlation. Stanovich and West (1999) found that participants with higher need for cognition were more likely to respond normatively on selection tasks requiring more attention to base rates, problems requiring ignoring of sunk costs and the Newcomb's problem, but no such correlation in the prisoner's dilemma. Hence, rational thought orientation seems to predict normative behavior in some instances but not in others. Deciphering the characteristics of tasks where it makes a difference will provide important insights into the functioning of our brain. This is beyond the scope of this paper and is left for future research.

*How Does Experiential Thinking Style Influence EU Violations?*

The correlation results between experiential scores from the REI and number of EU violations for the various studies is shown in Table 6. There is some weak evidence of a positive correlation between experiential engagement and aggregate EU violations in studies 3 to 5. The consolidated data show a correlation of .10, which is statistically significant, but low.

We, however, do get more statistical regularity in the data on proceeding from aggregate violations to individual violation types (Table 7). People with higher experiential thinking seem to be more prone to the impossibility effect and less so to ambiguity aversion.

*Correlation with the impossibility effect*. Experiential thinking correlates positively with the impossibility effect in all the studies (Table 7). Interestingly, the effect is more pronounced when access to the experiential system is facilitated, that is, in the experiential priming and the cognitive load conditions where the correlations are significant at the $p < 0.01$ level. Also, at the consolidated level the correlation is $r$ (743) = .20, $p \sim 0$. This finding is supported by data from study 6, which shows that experiential thinkers are significantly more optimistic in low probability gain situations (question 5) indicating higher degree of overweighting of low probabilities $r$ (164) = .26, $p < .001$, consistent with the results shown above.

Rottenstreich and Hsee (2001) found that the probability weighting function is more S-shaped for lotteries with affect-rich outcomes compared to lotteries with affect-poor outcomes, that is, higher overweighting and underweighting of small and large probabilities respectively was seen with affect-rich outcomes. This is because affect-rich outcomes "elicit greater degrees of hope and fear and, therefore, larger jumps at the

endpoints" (Rottenstreich & Hsee, 2001, p. 186). Their explanation follows from the observation that mental imagery, that underlies emotion, is insensitive to intermediate probabilities (Elster & Loewenstein, 1992). Their account is also consistent with the "risk as feelings" model of Loewenstein, Weber, Hsee, and Welch (2001).

The positive correlation observed between the impossibility effect and experiential thinking style is consistent with this literature since people high in their experiential thinking can be expected to have a higher degree of affective processing in their decision making. Indeed, study 6 shows that experiential thinkers do not agree with the notion that logical analysis rather than feeling good about a choice option should dictate choice, $r$ (164) = -.43, $p \sim 0$, consistent with the notion of emotion being an integral part of experiential thinking. In this case, affect-rich outcomes and a higher experiential thinking orientation produce equivalent behaviors. However, we notice that experiential thinking and the certainty effect are independent. Higher affective processing does not seem to be affecting behavior at the certainty end of the probability scale unlike the findings of the literature referred to above. This difference in behavior at the two ends of the probability scale can be explained by the presence or absence of mental imagery. A small probability of occurrence of an outcome is different from a probability of 0 as the former invokes a mental image while the latter does not. Hence, experiential thinking exerts influence on the impossibility effect by invoking mental images of outcomes in lotteries of small probability, the influence due to the imagery being greater for people high in experiential thinking. However, a high probability of an outcome and the outcome occurring with certainty are similar from the affective processing perspective to the extent that both evoke mental images of the outcome that will potentially be experienced.

Hence, in this case, there is no incremental effect of the evoked mental imagery in the decision making process thereby reducing the influence of experiential thinking. This presence and absence of correlation of experiential thinking with the impossibility and certainty effects respectively, shows that there are fundamentally different mental processes in operation at the two ends of the probability scale. Experiential thinking is predictive of behavior at the impossibility end but provides no information at the certainty end.

*Correlation with ambiguity aversion*. There is an inverse relation, albeit weak, between experiential thinking and ambiguity aversion. Although correlations in 3 out of the 5 studies are insignificant, all of them have the same sign and the correlation for the consolidated data is significant, $r$ (743) = -.13, $p < .001$. In addition, study 6 shows that experiential thinkers agree less with the decision rule that advises ambiguity avoidance, $r$ (164) = -.16, $p < .05$, consistent with the pattern observed in the choice studies. The tendency of experiential thinkers to overweight small probabilities, as established in the previous result, makes them relatively more insensitive to intermediate probabilities between 0 and 1. This insensitivity causes them to be relatively unperturbed by unknown intermediate probabilities. The people low in experiential thinking are more sensitive to intermediate probabilities and therefore care more about them. Higher ambiguity aversion comes about when people are ignorant about the probabilities that they care about. This can explain the negative correlation observed between ambiguity aversion and experiential thinking. Finally, it needs to be pointed out that the effect observed is weak and more research is required to establish it further.

*What Effect Does Increasing Access to the Rational System Have on EU Performance?*

*Rational priming*. In study 2, participants were primed with simple math questions before making choices in the test questionnaire. The result shows a significant improvement in EU performance on analytical priming (Table 8). There is an improvement of about 10% in EU compliance with a small to medium effect size, $d$ = 0.30 (Cohen, 1992), and shows that increased access to the rational system helps people in decision making under risk. It must be noted that though the effect size is small, considering the large number of decisions under risk that one takes in one's lifetime, the cumulative lifetime effect on an individual may indeed be very significant.

*Acting as an agent*. In study 4, participants made choices on behalf of another abstract entity. This manipulation was intended to be logically equivalent to analytical priming as it was expected to increase access to the rational system by suppressing the experiential system. An improvement in performance was observed, but it did not reach statistical significance (Table 8). Arguably, the manipulation was not strong enough given that the participants were placed in an artificial role of an agent.

*What Effect Does Increasing Access to the Experiential System Have on EU Performance?*

*Experiential priming.* In study 3, participants were primed with questions where they expressed their feelings before making choices in the test questionnaire. Similar to the analytical priming condition, the results show a significant improvement in EU performance (Table 8) with small effect size, $d$ = 0.22.

*Cognitive load*. In study 5, participants were subjected to a cognitive load prior to making choices in the test questionnaire. This manipulation was intended to be logically equivalent to experiential priming as it was expected to increase access to the experiential

system by limiting the capacity of the rational system. Consistent with the results of experiential priming, a significant improvement in performance was observed (Table 8) with slightly higher effect size, $d = 0.26$.

These results support the views expressed in Damasio's somatic marker hypothesis which established the link between emotional processing and rational decision making. They also indicate that experiential thinking is no worse than rational thinking in meeting coherence requirements of expected utility theory. This issue is discussed further in the concluding section.

*Do People With Certain Thinking Styles Respond More Favorably to Priming Manipulations Than Others?*

The previous result suggests that people improve their EU performance when they are subjected to rational or experiential priming. The question raised here is whether this is true across all thinking styles. The EU violation data for the category wise classification (refer to Table 2 for category classification) of the participant pool based on thinking styles is shown in Table 9 for all the studies. The EU performance in each of the conditions is compared to that in the base case. Statistical significance was hard to achieve in many of the cases due to smaller sample sizes. However, the pattern that stands out clearly is that there is improvement for all categories in all the studies except those classified as high rational-high experiential. In fact, participants in this category did worse in two of the four conditions. If we combine the other three categories, we achieve significant improvements in the rational priming condition, $t = 2.77$, $p < .01$, $d = 0.40$, the experiential priming condition, $t = 2.45$, $p < .05$, $d = 0.31$, and the cognitive load condition, $t = 2.33$, $p < .05$, $d = 0.31$. This suggests that people who are both highly

rational and highly experiential do not seem to respond positively, from an EU perspective, to conditions manipulating their relative access to the two systems. This interaction of the two systems in the EU context is interesting as it is *not* consistent with the related finding of Epstein (1998), who reported that people who were high in both rational as well as experiential orientation were *better* adjusted both interpersonally and intrapersonally. A potential explanation for this interaction effect is attempted in the concluding section.

*Are Certain Types of EU Violations More Responsive to Priming Manipulations Than Others?*

The specific pattern that emerges from the data on the different violation types (Table 10) is that improvements are mostly significant only in the impossibility effect. The common ratio effect shows no change from the base case, while the common consequence effect seems to improve, albeit insignificantly, on improving access to the rational system, but not the experiential system. In case of the impossibility effect, all improvements are significant, while the certainty effect shows weaker signs of improvement. The results for ambiguity aversion are insignificant. These results are only directional and further experiments with a larger number of tests are needed to establish these results further.

*Does Using More Time for Decision Making Lead to Lower EU Violations?*

As mentioned earlier, reaction times of the participants were recorded for each test question. In order to verify the validity and usefulness of this data, prior to tackling the issue of EU violations, we can test certain predictions of relationships between thinking styles and reaction times postulated in CEST. According to CEST, the rational

system uses sequential processing and is slow and deliberative, while the experiential system uses associative processing and is fast and intuitive. This leads us to five specific predictions:

1. Time taken by the high rational group is *more* than time taken by the low rational group.

2. Time taken by the high experiential group is *less* than time taken by the low experiential group.

3. The high rational–low experiential category will take the *maximum* time amongst all 4 categories.

4. Experiential priming will lead to the *fastest* reaction times of all conditions.

5. Acting as agent will lead to the *slowest* reaction times of all conditions.

Analytical priming increases access to the slower rational system, but can speed up reaction times by making information processing more efficient. Cognitive load, on the other hand, increases access to the faster experiential system, but can slow down reaction times due to less availability of cognitive resources. Hence, specific predictions on these conditions were not possible.

The experimental results support all five predictions. Specifically,

1. High rational group took more time than the low rational group, $t = 2.06$, $p < .05$.

2. High experiential group took less time than the low experiential group, $t = 1.76$, $p < .1$.

3. The high rational–low experiential category took more time than (a) the high rational–high experiential category, $t = 2.95$, $p < .01$; (b) the low rational–high

experiential category, $t = 2.69$, $p < .01$; and (c) the low rational–low experiential category, $t = 2.92$, $p < .01$.

4. Experiential priming produced faster reaction times than (a) the base case, $t = 3.51$, $p < .001$; (b) the analytical priming condition, $t = 2.01$, $p < .05$; (c) the acting-as-agent condition, $t = 5.36$, $p \sim 0$; and (d) the cognitive load condition, $t = 2.20$, $p < .05$.

5. The acting-as-agent condition had slower reaction times than (a) the base case, $t = 2.62$, $p < .01$; (b) the analytical priming condition, $t = 3.41$, $p < .001$; and (c) the cognitive load condition, $t = 2.62$, $p < .01$.

Correlation analysis reveals significant *positive* correlation between reaction times and EU violations in the base case, $r$ (174) = .16, $p < .05$, and the cognitive load condition $r$ (131) = .17, $p < .05$, and no significant correlation in the other three conditions. Greater deliberation does not seem to help in EU compliance. If anything, it may lead to more violations, consistent with findings of Wilson and Schooler (1991) who reported that respondents who analyzed reasons for a choice made more suboptimal decisions than those who did not. The assumption here is that people analyzing reasons for their choices are more likely to have higher response times. Wilson and Schooler (1991) go on to suggest that "people are often unaware of exactly why they feel the way they do about an attitude object. When they reflect about their reasons, they thus focus on explanations that are salient and plausible. The problem is that what seems like a plausible cause and what actually determines people's reactions are not always the same thing (Nisbett & Wilson, 1977)" (p. 182).

*How do the Different Types of EU Violations Correlate?*

The correlations between the different types of EU violations, for the aggregate participant pool, reveal two significant results, a positive correlation between the common consequence effect and the certainty effect and a negative correlation between the impossibility effect and ambiguity aversion (Table 11). In addition, the absence of a correlation between the impossibility effect and the certainty effect, the twin biases arising from the probability weighting function, is particularly interesting. Brief discussions of the correlation results are presented next.

*People committing common consequence violations are more likely to exhibit the certainty effect*. This result is not surprising as the certainty effect constitutes the primary explanation for the Allais paradox type of violations through Rank Dependent EU models. This paper views the problem from the individual differences perspective and it is comforting to note that the existing resolution of the Allais paradox is supported by the present findings.

*The impossibility effect and the certainty effect are independent*. Several functional forms have been offered in the literature for the probability weighting function. It has been established that the weighting function is inverse-S shaped, with small probabilities overweighted and mid and high probabilities underweighted. There are two main classes of functions, differing in the number of parameters used. Kahneman and Tversky (1992) proposed a one parameter weighting function,

$$w(p) = \frac{p^g}{[p^g + (1-p)^g]^{1/g}}, \tag{1}$$

with $g = 0.61$ as the median value. The important aspect of this function for our current purposes is that it implies a perfect correlation between the over weighting of small probabilities and the under weighting of large probabilities, that is, as $g$ increases, the curve becomes flatter with a simultaneous reduction in both the over and under weighting of low and high probabilities respectively. If we assume that the extent of over and under weighting of probability drive the propensity of exhibiting the impossibility and certainty effects respectively, then the one parameter model will imply a significant positive correlation between the occurrence of the two vio lations.

A two parameter weighting function, called "linear in log odds,"

$$w(p) = \frac{dp^g}{dp^g + (1-p)^g}, \tag{2}$$

has been used by Lattimore, et al. (1992), Goldstein and Einhorn (1987), Tversky and Fox (1995), Birnbaum and McIntosh (1996), Kilka and Weber (2001) and Gonzalez and Wu (1999). Gonzalez and Wu (1999) gave the parameters a psychological interpretation, where $d$ represents the "attractiveness" or elevation, and $g$ represents the "discriminability" or curvature of the weighting function. Attractiveness refers to the degree of over or underweighting and discriminability refers to the sensitivity to changes in probability in an interval bounded away from 0 and 1. Hence, as attractiveness increases, w($p$) increases for all values of $p$, while as discriminability decreases, w($p$) increases for $p$ near 0 and decreases for $p$ near 1. This model is shown to fit the empirical data better than the one parameter model and is also intuitively more appealing (Gonzales

& Wu, 1999). Assuming that the values of $d$ and $g$ characterizing individuals are uncorrelated, a reasonable assumption as the two parameters represent distinct psychological constructs, it is easy to see that the two parameter model implies the independence of the impossibility and the certainty effect, in contrast to the one parameter model. The findings in this study confirm this.

*People exhibiting the impossibility effect are less likely to exhibit ambiguity aversion.* It appears that experiential thinking mediates this inverse relationship between the impossibility effect and ambiguity aversion. As reported in the section on research question 2, experiential thinking is positively correlated with overweighting of low probabilities and negatively correlated with ambiguity aversion. Research on a more technical derivation of this relationship drawing on the nature of the probability weighting function and sub-additivity of subjective probability judgments (Schmeidler, 1989) is in progress and will be reported elsewhere.

*Are There Any Gender Based Differences in Thinking Styles and EU Violations? Does Influencing Access to the Rational or the Experiential System Affect Men and Women Differently?*

There are significant gender differences in self reported thinking styles (Table 12). Men consider themselves as having higher rational ability, $t = 4.72$, $p < .00001$, and a higher overall rational thinking orientation, $t = 3.73$, $p < .001$, while women consider themselves having higher experiential ability, $t = 1.75$, $p < .1$, higher experiential engagement, $t = 3.13$, $p < .01$ and as a result a higher overall experiential thinking orientation, $t = 2.98$, $p < .01$. These data are consistent with Pacini & Epstein (1999; p. 979, Table 5) who find significant gender differences in all but rational engagement.

Women exhibited a higher propensity for EU violations, driven primarily by more violations in the common consequence and the impossibility effects (Table 13). Men perform better in all the conditions (Table 14), but significantly so on analytical priming, $t = 1.96$, $p < .05$ and acting-as-agent, $t = 1.75$, $p < .1$. Note that the statistical significance shown in Table 14 is for the gender wise change in EU performance compared to the base case. Interestingly, women and men improve the maximum when primed on their thinking orientation. Hence, males show the maximum improvement on analytical priming, $t = 2.33$, $p < .05$ and females show the maximum improvement on experiential priming, $t = 1.85$, $p < .1$, in line with their predominant thinking orientations.

## Conclusion

The formulation of the expected utility theory marked a watershed in the study of decision making. Based on a set of appealing axioms it was elegant, parsimonious and analytically tractable. In the early days it enjoyed the dual status of a normative as well as a descriptive theory of choice and found application in a wide variety of research areas. Over the last few decades, however, the descriptive validity of EU has been seriously questioned. A large number of empirical studies have established systematic deviations of human choice from those predicted by EU. There is, however, considerable variation in individual performance with significant proportions of the participant pools both conforming to and violating EU. A natural question which arises is whether there are any personality characteristics that drive such behaviour. Identification of such variables may help predict choice behaviour at the level of the individual decision maker.

In this paper, individual differences in choice behaviour under uncertainty are explored using thinking orientations or styles, a concept theorized and established in the

dual systems literature (see Chaiken & Trope, 1999) in social psychology, as the predictor variable. In addition, the effect on choice performance of increasing the relative access of one thinking system or the other is explored. Five different types of choice questions are used, each testing a different aspect of EU, namely (a) the common ratio effect, (b) the common consequence effect, (c) the impossibility effect, (d) the certainty effect, and (e) ambiguity aversion.

The key findings in this paper can be summarised as follows:

1. EU violations are independent of rational thinking orientation.

2. Experiential thinking correlates positively with the impossibility effect, negatively with ambiguity aversion, and is independent of the other types of EU violations.

3. Increasing access to the rational system or experiential system improves EU performance for all participants, except for those high on both rational and experiential thinking dimensions.

4. Greater deliberation does *not* lead to better EU performance.

5. The common consequence effect and certainty effect are positively correlated and the impossibility effect and ambiguity aversion are negatively correlated.

6. There are interesting gender differences in choice behaviour, specifically, (a) consistent with gender stereotypes, men are more rationally oriented and women are more experientially oriented; (b) women violate EU more often than men; and (c) men and women improve EU performance the most when primed on their respective thinking orientations.

In addition, the distribution of EU violation is unimodal, showing that society is not divided into "EU haves" and "EU have-nots." Also, consistent with the subcertainty hypothesis of prospect theory (Kahneman & Tversky, 1986), the certainty effect is more prevalent than the impossibility effect. We can think of the impossibility and certainty effects to be driven by the magnitude of over or underweighting, that is, the higher the value of $|w(p) - p|$ for values of $p$ near 0 or 1, the higher the propensity to commit these violations. Consequently, using $d = 0.77$ and $g = 0.44$, the median values of the two parameter probability weighting model (Gonzales & Wu, 2005), we get $|w(.01) - .01|/|w(.99) - .99| = 0.60$ and $|w(.05) - .05|/|w(.95) - .95| = 0.58$. Consistent with this prediction, the ratio between the two effects was found to be 0.58 in the first case and 0.62 in the second.

The findings in this paper provide some evidence that none of the two systems is individually better equipped than the other in processing choice under uncertainty. This is interesting as it is largely in contrast with the findings in the literature on reasoning and judgment where thinking styles have been found to predict human performance (Stanovich & West, 1997, 1998; Sá, West, & Stanovich, 1999). Why is a rational thinking orientation predictive of normative performance in a bayesian selection task, a sunk cost problem and the Newcomb's problem but not so in choice under uncertainty? One answer could lie in questioning the validity of EU as the normative model of choice. The other answer could lie in our cultural evolution. According to Epstein (2003), "the rational system is an inferential system that operates according to a person's understanding of the rules of reasoning and of evidence, which are mainly culturally transmitted." Evidently, the rules of reasoning and evidence residing in the rational

system do not include normative choice under conditions of uncertainty. Indeed, the study of decision making under uncertainty does not find a place in our formal education system and consequently has not been ingrained in our rational processing system, unlike the rules of logic that helps solve a sunk cost problem.

The empirical results reported here suggest that rational thinking orientation has no impact on EU violations. This is true both from the perspective of making choices and expressing agreement with the EU axioms. If people who are rationally oriented and who give more importance to logical thinking are not more likely to abide by the rules of the EU calculus, then the status of EU as a rational theory of choice need to be reconsidered.

Some of the results in this paper can be explained through an elementary model of the dual systems approach (Figure 1). A similar framework has been used earlier by Loewenstein and Donoghue (2004) in a different context. The stimulus is a decision problem which the individual is contemplating. On receipt of the problem, it is directed to the two systems of thought, the rational system and the experiential system, which are independent and interactive as envisaged in CEST. Neuroscientists have discovered neural connections directed both ways between the prefrontal cortex and the more primitive brain systems. The outputs of the two thinking systems then drive behavior.

Thinking dispositions can be envisaged as the relative capacities of the activation channels, A and B, which could be the number of neural connections between the processing system and the perceptual system. Hence, a person with a high rational and low experiential thinking orientation will have a high capacity activation channel A and a low capacity activation channel B. In general, when a choice problem is encountered, more of the activation energy will be directed towards the rational system, which will

then be responsible for bulk of the processing required for problem solving. This feature should be understood as a characteristic of the individual. Of course, the actual activation can vary depending on different contextual factors of the choice situation. For a given problem, an individual with higher capacity channel A than another will activate his rational system more than the other. The other thinking dispositions can be described similarly.

It can be theorized, based on the evidence in this paper, that neither the experiential system nor the rational system is superior to the other in EU compliance. However, EU performance depends on a proper synchronization of the two systems which depends on the strength of the connectivity between the two systems, C. Note that strength of C is independent of one's thinking style. Hence, it is posited that the capacity of the activation channel C directly influences normative responses to problems of choice under uncertainty. A low capacity C coupled with high capacity channels A and B lead to the conflicts between the two systems responsible for inferior decision making reported in the literature (Stanovich & West, 2000; Epstein, 2003).

In the base case scenario in the experiments reported in this paper, neither rational nor experiential orientation showed superior overall EU performance. The individual differences in performance was due to the differences in the strength of the interconnectivity, C, which drives the coordination between the two systems. External inducement of a thinking style through priming manipulations, not only enhances the capacity of the respective channel, A or B, depending on the manipulation, but also increases the capacity of the interactive channel C. As a result of the better synchronization due to stronger interconnectivity between the two systems, we observe

an improvement in performance in the priming conditions. Finally, people having a high orientation towards both systems, use up more of the limited activation energy in channels A and B, with less available to take advantage of the increased capacity of channel C induced by the priming activities. Hence, we observe that high rational-high experiential participants do not perform as well as the others in the priming conditions.

In conclusion, the findings in this paper should be treated as directional. More research along similar lines is needed to further establish the effects of thinking orientations on choice under risk and uncertainty. An interesting dimension for future research, not pursued in this paper, is to explore the link between the qualities of each processing system with choice behavior. Does a person with better cognitive ability or a better experiential system make more normative decisions in choice problems? Rather than neglecting individual differences as a nuisance, we could use it as a tool to better our understanding of the complex processes underlying human choice behavior.

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Table 1

*Summary of the Experimental Studies*

| Study | Manipulation | Experimental material |
|---|---|---|
| 1 | Base case | REI, EU test questionnaire |
| 2 | Analytical priming | REI, analytical priming and EU test questionnaires |
| 3 | Experiential priming | REI, experiential priming and EU test questionnaires |
| 4 | Acting-as-agent | REI, modified EU test questionnaire |
| 5 | Cognitive load | REI, cognitive load administration, EU test questionnaire |
| 6 | Decision rules | Decision rules questionnaire |

Table 2

*Summary Statistics of the Different Thinking Categories*

| | | Rational | | Experiential | |
|---|---|---|---|---|---|
| Category | *N* | *M* | *SD* | *M* | *SD* |
| High R – High E | 191 | 4.00 | 0.27 | 3.65 | 0.31 |
| High R – Low E | 180 | 4.03 | 0.23 | 2.74 | 0.35 |
| Low R – High E | 182 | 3.17 | 0.37 | 3.69 | 0.30 |
| Low R – Low E | 190 | 3.23 | 0.36 | 2.88 | 0.31 |

Table 3

*Summary Statistics of the Different Thinking Orientations*

| | | Rational | | Experiential | |
|---|---|---|---|---|---|
| Category | *N* | *M* | *SD* | *M* | *SD* |
| High R | 371 | 4.01 | 0.25 | 3.21 | 0.56 |
| Low R | 372 | 3.20 | 0.37 | 3.28 | 0.51 |
| High E | 373 | 3.59 | 0.53 | 3.67 | 0.31 |
| Low E | 370 | 3.61 | 0.50 | 2.81 | 0.34 |

Table 4

*Correlations Between Rationality Scores from the REI and the Number of EU Violations*

| Study | *N* | $R_{ab}$ | $R_{eng}$ | R |
|---|---|---|---|---|
| Base case | 174 | -.12 | -.01 | -.08 |
| Analytical priming | 115 | .07 | .11 | .11 |
| Experiential priming | 154 | -.05 | .07 | .01 |
| Acting-as-agent | 169 | -.02 | -.02 | -.02 |
| Cognitive load | 131 | -.03 | -.04 | -.04 |
| Consolidated | 743 | -.04 | .02 | -.01 |

*Note.* $R_{ab}$ = rational ability; $R_{eng}$ = rational engagement; R = rational aggregate.

Table 5

*Correlations Between Rationality Scores from the REI and the Types of EU Violations*

| Study | *N* | CRE | CCE | IE | CE | AA |
|---|---|---|---|---|---|---|
| Base case | 174 | -.15* | -.05 | -.07 | .03 | .06 |
| Analytical priming | 115 | .09 | .05 | -.13 | .11 | .18* |
| Experiential priming | 154 | .01 | -.01 | -.02 | .04 | -.01 |
| Acting-as-agent | 169 | .06 | -.01 | -.04 | -.10 | .04 |
| Cognitive load | 131 | .09 | -.08 | -.04 | -.11 | .07 |
| Consolidated | 743 | .01 | -.03 | -.05 | -.01 | .07* |

*Note.* CRE = common ratio effect; CCE = common consequence effect; IE = impossibility effect; CE = certainty effect; AA = ambiguity aversion.

*$p < .10$. **$p < .05$.

Table 6

*Correlations Between Experiential Scores from the REI and the Number of EU Violations*

| Study | *N* | $E_{ab}$ | $E_{eng}$ | E |
|---|---|---|---|---|
| Base case | 174 | -.10 | .02 | -.04 |
| Analytical priming | 115 | .01 | -.02 | -.01 |
| Experiential priming | 154 | .07 | .16* | .13* |
| Acting-as-agent | 169 | .04 | .13* | .10 |
| Cognitive load | 131 | .10 | .20** | .16* |
| Consolidated | 743 | .02 | .10*** | .07* |

*Note.* $E_{ab}$ = experiential ability; $E_{eng}$ = experiential engagement; E = experiential aggregate.

*$p < .10$. **$p < .05$. ***$p < .01$.

Table 7

*Correlations Between Experiential Scores from the REI and the Types of EU Violations*

| Study | *N* | CRE | CCE | IE | CE | AA |
|---|---|---|---|---|---|---|
| Base case | 174 | -.07 | .02 | .20*** | -.08 | -.20*** |
| Analytical priming | 115 | .04 | -.04 | .16* | -.13 | -.06 |
| Experiential priming | 154 | .00 | .06 | .24*** | .03 | -.06 |
| Acting-as-agent | 169 | .16** | .05 | .14* | .01 | -.16** |
| Cognitive load | 131 | .15* | .07 | .26*** | .02 | -.13 |
| Consolidated | 743 | .05 | .03 | .20**** | .07* | -.13**** |

*Note.* CRE = common ratio effect; CCE = common consequence effect; IE = impossibility effect; CE = certainty effect; AA = ambiguity aversion.

*$p < .10$. **$p < .05$. ***$p < .01$. ****$p < .001$.

Table 8

*Summary Statistics of EU Violations*

| Study | *N* | *M* | *SD* |
|---|---|---|---|
| Base case | 174 | 5.53 | 1.72 |
| Analytical priming | 115 | 5.01*** | 1.79 |
| Experiential priming | 154 | 5.14** | 1.75 |
| Acting-as-agent | 169 | 5.31 | 1.87 |
| Cognitive load | 131 | 5.07** | 1.83 |

*Note.* Statistical significance is based on comparison with the base case.

*$p < .10$. **$p < .05$. ***$p < .01$.

Table 9

*Summary Statistics of EU Violations Based on Thinking Categories*

| Study | HRHE<br>*M*(*n*, *SD*) | HRLE<br>*M*(*n*, *SD*) | LRHE<br>*M*(*n*, *SD*) | LRLE<br>*M*(*n*, *SD*) |
|---|---|---|---|---|
| Base case | 5.46(50, 1.9) | 5.48(40, 1.5) | 5.55(40, 1.8) | 5.64(44, 1.7) |
| Analytical priming | 5.29(35, 2.0) | 4.86(29, 1.4)* | 4.67(24, 2.2)* | 5.11(27, 1.6) |
| Experiential priming | 5.50(34, 1.8) | 4.75(36, 1.7)** | 5.20(45, 1.7) | 5.10(39, 1.8) |
| Acting-as-agent | 5.52(52, 2.1) | 5.27(37, 1.6) | 5.45(38, 1.8) | 4.98(42, 1.8)* |
| Cognitive load | 5.30(20, 1.8) | 4.76(38, 2.0)* | 4.97(35, 1.8) | 5.34(38, 1.7) |

*Note.* Statistical significance is based on comparison with the base case. HRHE = high rational-high experiential; HRLE = high rational-low experiential; LRHE = low rational-high experiential; LRLE = low rational-low experiential.

*$p < .10$. **$p < .05$.

Table 10

*Summary Statistics of EU Violations Based on Type of Violation*

| Study | *N* | CRE *M*(*SD*) | CCE *M*(*SD*) | IE *M*(*SD*) | CE *M*(*SD*) | AA *M*(*SD*) |
|---|---|---|---|---|---|---|
| Base case | 174 | 0.87(0.7) | 1.01(0.8) | 0.95(0.9) | 1.45(0.8) | 1.25(0.8) |
| Analytical priming | 115 | 0.84(0.7) | 0.89(0.8) | 0.71(0.8)** | 1.37(0.8) | 1.20(0.7) |
| Experiential priming | 154 | 0.88(0.7) | 1.01(0.8) | 0.77(0.9)* | 1.32(0.8) | 1.14(0.7) |
| Acting-as-agent | 169 | 0.93(0.8) | 0.91(0.8) | 0.79(0.9)* | 1.34(0.8) | 1.34(0.6) |
| Cognitive load | 131 | 0.95(0.7) | 0.99(0.8) | 0.77(0.9)* | 1.24(0.8)** | 1.11(0.7) |

*Note.* The data represents the mean number of violations out of 2 tests of each type. Statistical significance is based on comparison with the base case. CRE = common ratio effect; CCE = common consequence effect; IE = impossibility effect; CE = certainty effect; AA = ambiguity aversion.

*$p < .10$. **$p < .05$.

Table 11

*Correlations Between the Different Types of EU Violations*

| *N* = 743 | CRE | CCE | IE | CE |
|---|---|---|---|---|
| CCE | .07 | | | |
| IE | .06 | .06 | | |
| CE | .00 | .17*** | .06 | |
| AA | -.04 | -.05 | -.11*** | .01 |

*Note.* CRE = common ratio effect; CCE = common consequence effect; IE = impossibility effect; CE = certainty effect; AA = ambiguity aversion.

*$p < .10$. **$p < .05$. ***$p < .01$.

Table 12

*Gender Wise Thinking Styles Based on the REI*

| | Male (*N* = 292) | | Female (*N* = 451) | |
|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* |
| $R_{ab}$ | 3.51 | 0.58 | 3.30*** | 0.61 |
| $R_{eng}$ | 3.86 | 0.57 | 3.81 | 0.65 |
| R | 3.69 | 0.48 | 3.55*** | 0.53 |
| $E_{ab}$ | 3.20 | 0.53 | 3.27* | 0.54 |
| $E_{eng}$ | 3.15 | 0.65 | 3.30*** | 0.62 |
| E | 3.17 | 0.54 | 3.29*** | 0.53 |

*Note.* $R_{ab}$ = rational ability; $R_{eng}$ = rational engagement; R = rational aggregate; $E_{ab}$ = experiential ability; $E_{eng}$ = experiential engagement; E = experiential aggregate.

*$p < .10$. **$p < .05$. ***$p < .01$.

Table 13

*Gender Wise EU Violations by Violation Type*

| | Male (*N* = 292) | | Female (*N* = 451) | |
|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* |
| CRE | 0.90 | 0.72 | 0.89 | 0.72 |
| CCE | 0.87 | 0.76 | 1.03*** | 0.76 |
| IE | 0.72 | 0.86 | 0.87** | 0.86 |
| CE | 1.30 | 0.80 | 1.38 | 0.77 |
| AA | 1.25 | 0.69 | 1.20 | 0.68 |
| Total | 5.04 | 1.88 | 5.37** | 1.73 |

*Note.* The data represents the mean number of violations out of 2 tests of each type. CRE = common ratio effect; CCE = common consequence effect; IE = impossibility effect; CE = certainty effect; AA = ambiguity aversion.

*$p < .10$. **$p < .05$. ***$p < .01$.

Table 14

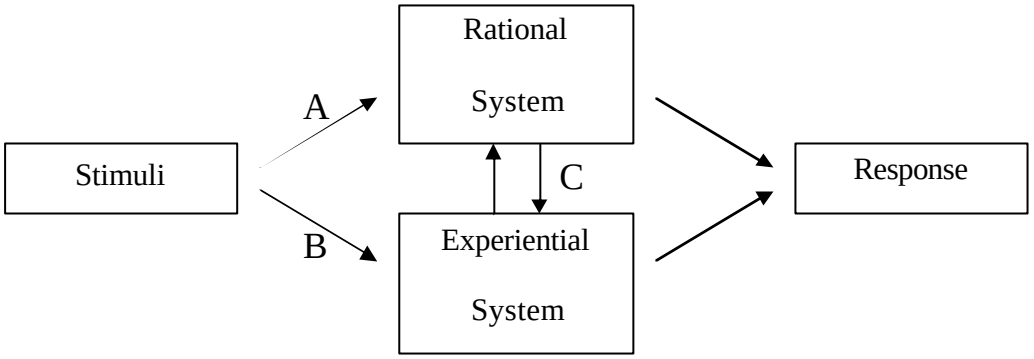
*Gender Wise EU Violations by Experimental Manipulation*

| | Male ($N$ = 292) | | | Female ($N$ = 451) | | |
|---|---|---|---|---|---|---|
| Study | *n* | *M* | *SD* | *n* | *M* | *SD* |
| Base case | 70 | 5.44 | 1.98 | 104 | 5.59 | 1.52 |
| Analytical priming | 41 | 4.56** | 1.90 | 74 | 5.26 | 1.70 |
| Experiential priming | 67 | 5.13 | 1.71 | 87 | 5.14* | 1.78 |
| Acting-as-agent | 63 | 4.98 | 1.92 | 106 | 5.51 | 1.82 |
| Cognitive load | 70 | 4.80* | 1.85 | 80 | 5.24 | 1.81 |

*Note.* Statistical significance is based on comparison with the base case.

*$p < .10$. **$p < .05$.

*Figure 1.* Elementary model of decision making with dual systems.



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