Title: **Risk-Sensitive Decision - Making Examined Within an Evolutionary Framework.**

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Abstract: *The present paper is an attempt to present the process of dealing with risk within the Evolutionary approach in psychology. As a new approach to Decision-making it uses knowledge and principles from modern Darwinian theories in research of the human mind. In this view, the mind consists of a rich array of information-processing mechanisms that were designed by natural selection to solve adaptive problems that were recurrent in hominid evolution.*

Here we review how this way of thinking about psychology guided our research on two well-established phenomena in the human decision-making literature - the ambiguity avoidance effect and the framing effect - and how evolutionary thinking helped us to synthesize the ideas from risk-sensitive foraging models and construct a "realistic" risk perception. These violations were often used to showcase that the human mind is predisposed against optimal decision making. We argue that the human mind is fine-tuned to solve complex decision tasks that had been recurrent in hominid evolution. By studying the biases within the framework of risk-sensitivity theory, we demonstrate that to analyze and accept the risk, and arrive at a decision that is most likely to guarantee survival, humans take into account the mean outcome of an option, the variability, of the outcome, and their current goal. Thus, an evolutionary approach helps us reveal important features of human choice behavior and provides insights into the nature of human decision rationality. We further discuss the benefits and constraints of an evolutionary approach to the psychology of decision making and specify some general questions for future work needed to enrich our understanding of risk-sensitive human decision making.

RISK-SENSITIVE DECISION MAKING EXAMINED WITHIN AN EVOLUTIONARY FRAMEWORK

Decisions on alternative options often involve risks and uncertainties. Should we buy flood insurance or would we rather save the money? Do we prefer a high-risk or a low-risk stock market investment? When do we choose surgery rather than chemotherapy for cancer treatment?

All these decisions are at least partly based on uncertainty, uncertainty regarding the probabilities with which possible events will occur. In many economical, medical, or social situations, decisions under uncertainty can have serious consequences.

In the second half of this century, a theory of rational decision making was presented under the name of "expected utility theory" (Savage, 1954; Von Neumann & Morgenstern, 1947). The basic idea of this model is that, for each available option, the expected payoff that would be obtained if the alternative is chosen is calculated. We can determine the expected payoff of one option by summing the products of the probabilities and the values of the outcomes contingent on these probabilities. Assuming one aims at maximizing the payoff, one should choose the option with the highest expected payoff.

Much research in the psychological literature on human decision making has compared people's choices to expected utility theory. Although people generally accept the rationality of the axioms and rules of the theory once they have been pointed out to them, their actual choices often deviate from this normative model in a systematic and consistent way. In other words, people feel tempted to violate core principles of expected utility theory, even when they have been shown that this is "irrational." From these findings, it was concluded that "people lack the correct programs for many important judgmental tasks .... We have not had the opportunity to evolve an intellect capable of dealing conceptually with uncertainty" (Slovic, Fischhoff, & Lichtenstein, 1976, p. 174). Famous examples of such irrationality are the ambiguity effect (e.g., Ellsberg, 1961) and the framing effect (e.g., Tversky & Kahneman, 1981). The ambiguity effect occurs when people choose an option for which the probability information is explicitly stated over one for which it is either imprecise or lacking, even though both have the same expected utility. From the perspective of expected utility theory, options with the same expected utility should be treated as equivalent. Systematically preferring options with stated probability information over options with lacking probability information is considered irrational. Another demonstration of systematic violation of expected utility theory is called the framing effect, in which an identical pair of alternatives is framed in terms of either gains or losses as for instance, in the two messages "if breast cancer is detected early it can be treated before it becomes life threatening" versus "if breast cancer is not detected early it cannot be treated before it becomes life threatening." Tversky and Kahneman (1981) have shown that the way information is presented or framed influences people's choices. Such a pattern, however, is inconsistent with expected utility theory, which requires that decisions be made on the basis of absolute values regardless of the framing or phrasing of the context.

In the attempt to explain the incompatibilities of human decisions with normative models of rational choice, the judgment and decision-making literature has offered a bundle of different psychological mechanisms, which were proposed and investigated in the so-called Heuristics and Biases Program (Kahneman, Slovic, & Tversky, 1982).

Heuristics are strategies that simplify complex tasks. They "reduce the complex task of assessing probabilities and predicting values to simpler judgmental operations" and "make them tractable for the kind of mind that people happen to have." "In general they are quite useful, but sometimes they lead to severe and systematic errors" (Kahneman et al., 1982, pp. 3, xi).

The distinctive claim of the heuristics and biases approach is that the human brain is not able to capture complex statistical principles. Instead, simple rules of thumb--heuristics--develop reliably, and they enable humans to solve successfully many of those complex problems. The existence of these heuristics experimentally can be shown by predicting and demonstrating specific deviations from normative models that are expected to occur if a particular heuristic is adopted.

However, it has been criticized that most of these proposed heuristics only redescribe the observed behavior instead of being theory generated. They do not explain why human choices differ in particular ways from the context-free and consistency-based axioms of expected utility theory. As a result, it often remains unclear what mechanism elicits the distinctive features of human decision making.

In contrast to the heuristics and biases approach, the potential of studying decision making from an evolutionary perspective is that it can provide functional explanations as well as process models of psychological phenomena.

Consider the following gamble: One box contains 50 black and 50 white balls; another box also contains 100 black and white balls but in an unknown composition. Suppose you may pick a ball from one of these boxes and receive $100 if the ball is black. Which box would you draw from?

From the perspective of expected utility theory, both options are equivalent. The expected payoff given the 50/50 box is 0.5 x $100, which is $50. The same is true for the ambiguous box. There is no reason to think that black is more or less likely than white. Therefore, 0.5 will be assigned as the probability of winning. It follows that the expected payoff is also $50.

Nonetheless, when given this choice task, most people express a strong preference for the 50/50 box (Curley, S. P., Yates, J. F., & Abrams, R. A. (1986). Instead of solely considering the expected payoffs of the two options as prescribed by expected utility theory, people appear to be strongly influenced by the precision with which the relevant probabilities are stated. It seems that participants systematically avoid options with uncertain or ambiguous probability information, although both options are equal from the perspective of expected utility theory. Accordingly, the decisions that follow from this aversion to ambiguity fail to maximize the expected payoff in the long run and thus imply that ambiguity avoidance is an error. During the past 20 years of research, the ambiguity effect has been proven to be strong and reliable, and several times it has been shown that it persists even in the face of energetic attempts to eliminate it (Bowen, Qiu, & Li, 1994; Curley et al., 1986; MacCrimmon, 1968).

But why does the ambiguity effect occur? Basing our argument on evolutionary thinking, we propose that people may have evolved an adaptive decision-making mechanism designed to attend to variables important for making optimal decisions in the natural environment. But what are the ecologically relevant variables in the natural environment? To answer this question, we draw on a theory from the literature in behavioral ecology, the risk-sensitive foraging theory. The argument is the following: Real life has baselines, such as death, below which one must not fall. Suppose a forager needs a minimum of 250 calories to survive. Let us further suppose that two resource patches have the same expected payoffs of 250 calories but differ with respect to the variability of this expected payoff. Risk-sensitive foraging theory states that a forager ought to forage on the lower variance patch, because the lower variance patch is more likely to satisfy the minimum requirement of 250 calories. In other words, the lower variance patch less often provides outcomes of less than 250 calories than the high variance patch would do. However, if the minimum requirement is higher than the expected payoff of the patches--let us say it is 300 calories--then the best hope for surviving until tomorrow is to forage on the higher variance patch because the more variable outcome distribution provides an increased probability of obtaining the necessary amount of food. This model of optimal choice in ecological environments, the risk-sensitive foraging theory, provides a principled basis for predicting which circumstances will cause organisms to avoid uncertainty and which will cause them to prefer it (e.g., Stephens & Krebs, 1986) based on the relationship between the expected payoffs, variability of expected payoffs, and the current minimum requirement.

If people understand that the payoff of options with missing probability information is more variable than that for which the probability information is known, then, according to risk-sensitive foraging theory, the two options are not equivalent, even when they have the same mean payoff. Risk-sensitive foraging theory predicts that a decision maker will choose the option with lower payoff variance unless the minimum requirement in the given situation exceeds the expected payoff of this option. In a typical ambiguity experiment, there is no need or requirement specified; thus, there is no reason for a decision maker to choose the ambiguous, high-variance option.

It was predicted and found (Rode, Cosmides, Hell, & Tooby, 1999) that participants preferred the high-variability ambiguous option when the required number of black balls exceeded the expected number of black balls of the low-variability option (i.e., the known-probability box), and they selected the low-variance option when the minimum requirement was below the expected number. Thus, people were neither generally ambiguity avoiding, as was suggested in the decision-making literature, nor generally ambiguity seeking. They were--as predicted by the risk-sensitivity model--choosing in a way that maximizes the probability of satisfying their current need. Stated differently, people's behavior deviates from normative models of rational choice invented in the 19th century but is fully consistent with models of rational choice that have been proven to be adaptive and functional in an uncertain natural environment.

To summarize, the risk sensitivity analysis led to testable predictions of how humans would choose among options with different degrees of uncertainty. Contrary to what was proposed in the classical decision-making literature, the decisions were not irrationally biased against unknown probability distributions. Instead, humans seem to apply a complex but rational decision strategy that integrates three parameters when making decisions under uncertainty: the expected payoff of the available options, the variability of possible outcomes, and their current need (or the minimum requirement). Thus, the evolutionary approach revealed important features of human decision making under uncertainty. Without considering the decision-making tasks and their interaction with environmental resources from the perspective of evolutionary functionality, this structure of risky decision making would not have been revealed.

But this line of reasoning is not limited to artificial gambling problems. It is applicable to more complex ecological and social situations. The studies on framing effects discussed in the following section exemplify this applicatio

Another classical demonstration of systematic violation of expected utility theory, the so-called framing effect, was provided by Tversky and Kahneman (1981) in a study using a hypothetical life-death decision problem known as the Asian disease problem. The cover story of the Asian disease problem involves a hypothetical group context in which 600 anonymous people are infected by a fatal disease. The participants were asked to evaluate two alternative medical plans proposed to rescue the hypothetical patients at risk. One alternative was a sure thing (Plan A), whereas the other was a gamble (Plan B) of equivalent expected payoff. The outcomes of the two alternatives were presented under either a positive or a negative framing condition. In the positive framing condition, the choice outcomes were framed in terms of the opportunity for lives to be saved. The participants were told that if Plan A was adopted, one third of the hypothetical patients would be saved for certain; and if Plan B was adopted, there would be a one-third probability that all the hypothetical patients would be saved and a two-thirds probability that none of them would be saved. In contrast, in the negative framing condition, the same choice outcomes were framed in terms of lives lost. The participants were then told that if Plan A was adopted, two thirds of the hypothetical patients would die for certain; and if plan B was adopted, there would be a one-third probability that none of the hypothetical patients would die and a two-thirds probability that all of them would die.

Tversky and Kahneman (1981) demonstrated a reversal in risk preference as a result of how the same choice outcomes are phrased or framed. Given a binary choice, the majority of their participants (72%) preferred the sure outcome (Plan A) to its gamble equivalent (Plan B) when the choice outcomes were framed in terms of lives being saved. However, when the same outcomes framed in terms of lives lost were presented to another sample of participants, the majority of the participants (78%) favored the gamble outcome over the sure outcome. In the decision-making literature, such a framing effect is often considered to be a cognitive illusion that violates the invariance principle of expected utility theory. The invariance axiom requires a rational decision maker to have a consistent preference order among choice prospects independent of the way the prospects are presented or framed.

The literature on framing effects has shown that appearance or disappearance of a framing effect depends on various context and content variables embodied in a decision problem and on the other hand, it influences the way that risk is perceived and estimated.Thus, two main questions arise: How much do judgments and decisions depend on the way the problem is worded and what are some specific ways in which the wording of a problem influences the subject's reaction? probability and risk estimates are susceptible to a range of biases. Some of them are a natural result of a reliance on heuristics, others are a consequence of motivational factors, and still others arise from prior expectations or the way a problem is framed.
Let thinking on the following facts: Smoking causes more than one out of every six deaths in the US (Hilts, 1990, September 26). On the average, a male smoker who deeply inhales cigarettes smoke reduces his life expectancy by 8.6 years, and a female smoker who deeply inhales cigarete smoke loses 4.6 years (Cohen & lee, 1979). By one estimate, smoking only 1.4 cigarettes increases the odds of death by the same amount as living within 20 miles of a nuclear power plant for 150 years (Wilson, 1979, February).
These statistics illustrate some different ways that the vey same risk can be described. Perceptions of risk are highly subjective, and the value people place on preventive behaviors depends in part upon the way a particular risk is presented and the type of risk it is (Stone & Yates, 1991). For examole, Chauncey Starr has argues that people are willing to accept far greater "voluntary" risks (e.g., risks from smoking or skiing) than "involuntary" risks (e.g., risks from electric power generation).As Starr (1969, p.1235) puts it; "We are loathe to let others do unto us what we happily do to ourselves."
Risk perception is an exceedingly important topic - a topic that will only become more critial as the world faces tough decisions about the global environment, international security, medical epidemics, and so forth. But what do people mean when they talk about risk/ Is risk basically equivalent to the expected number of fatalities from a given action? What are the characteristics that make something appear risky? As it happens, perceptions of risk are often complicated. To most people, risk means much more than the expected number of fatalities from a particular course of action. Paul Slovic and his colleagues have uncovered three basic dimensions connected with public perception of risk. The first dimension, known as "dread risk", is characterized by a "perceived lack of control, dread, catastrophic potential, fatal consequences, and the inequitable distribution of risks and benefits" (Slovic, 19987, p.283). This dimension corresponds closely to the general public's perception of risk, and the most extreme examples of this type of risk have to do with nuclear weapons and nuclear power. The second dimension, called "unknown risks", involves those aspects of risk "judged to be unobservable, unknown, new, and delayed in their manifestation of harm". Genetic and

chemical technologies are extreme examples of this kind of risk. Finally, the last important dimension concerns the number of people who are exposed to a given risk. Although there are obviously a variety of other factors that influence the perception of risk - such as conservatism in probability estimation, the vividness or availability of a threat, and the recency of a catastrophe - a number of studies have replaced the three basic dimensions emphasized by Slovic and his colleagues. One of the most interesting results these researchers have found is that lay people differ quite a bit from experts in how they p[erceive risk (Slovic, Fischhoff, & Lichtenstein, 1979, April). Lay people do a moderately good job of estimating the annual fatalities from various risks, but their overall perceptions of risk are more related to factors such as “catastrophic potential” and “threat to future generations” than to annual fatalities. Experts, on the othe hand, do a very good job of estimating annual fatalities, and their perceptions of risk correlate highly with these fatality estimates. To take an example, the general public sees nuclear power a terrible risk, whereas experts tend to see it as a relatively minor risk. In fact, when Slovic and his associated (1979, April) asked students to rate 30 different activities and technologies in terms of risk, the students rated nuclear power as the single greatest risk. When a group of nationally respected risk assessors were presented with the same list, however, they rated nuclear power as twentieth - well behind riding a bicycle.These findings suggest that people pay more attention to verbal cues, such as how choice outcomes are framed or phrased, when ecologically more valid decision cues are absent. Framing effects thus should be better understood as a sign of ambiguity in risk preference.

Why was the risk-seeking preference amplified in small- and kinship-group contexts? Risk-sensitive foraging theory sheds light on this question. If we assume that for a group to survive as a whole, the number of group members has to be above a certain threshold (minimum requirement for group function), the risk-seeking option would be favored when the expected value of the sure option is below the minimum requirement. That is, saving only one-third of a highly interdependent small group may be the equivalent of functional death. Models of risk-sensitive foraging have provided some useful concepts and ideas for understanding group-context-sensitive risky choices. As discussed earlier in this article, when two foraging options have the same mean payoff but differ in their variance, a forager should be risk seeking and forage in the high-variance option when the mean payoff is below the minimum requirement for calories of daily intake. In contrast, if the mean expected payoff of the two foraging options is greater than the minimum requirement, the forager is better off foraging in the option with lower variance, as this decreases the chance of death.

Regarding the life-death problem, a minimum requirement can be expressed as the minimum required percentage of group members that have to be saved. Based on this mean-variance analysis, one can make further testable predictions. The previous findings (Wang, 1996a) suggest that the setting of a minimum requirement for saving lives is highest in a kinship context and lowest in a large-group context. Kinship is the first and foremost organizing force for social grouping throughout hominid evolution. The members in a kinship group, compared to other human groups, should be most cooperative and interdependent on each other. This high interdependence should foster a live-or-die-together risk attitude and increase the minimum requirement for saving kin members when one's kin group is at risk.

Following the above reasoning, people may favor a gamble option in small and family contexts even when the expected outcome of the gamble is substantially lower than its sure outcome alternative (Wang,1996a).

Given the preliminary human evidence of mean-variance sensitivity demonstrated in the studies discussed above, the mean-variance model might be a useful alternative theoretical framework for understanding human social and ecological decisions.

BENEFITS OF AN EVOLUTIONARY APPROACH

Evolutionary thinking directs researchers to identify socially and ecologically important domains and psychologically important dimensions. The two independently conducted studies on ambiguity effect and framing effect shared a similar evolutionary thinking and borrowed ideas from risk-sensitive foraging models. On such common theoretical bases, we were able to derive testable predictions in different task domains. Generally, it is predicted that people are sensitive to mean, variability, and individual aspiration levels when making decisions. It is further predicted that participants will integrate those pieces 0f information to apply the following decision rule: Be risk seeking and choose the option with higher variance if your aspiration level exceeds the mean outcome of the low-variance option. If, however, the mean outcome of the lower variance option satisfies your aspiration level, be risk averse and choose the lower variance option.

Although evolutionary thinking can be used as a useful framework for constructing research questions and designs, proximal (psychological) mechanisms can be implemented in many different ways.

In the cases we just analyzed the risk sensitivity model is applied in a relatively simple and straightforward way. The participants in most of experiments above faced two-alternative choices with identical expected payoffs and different payoff variabilities. However, real decisions may be much more complex in their statistical structure. Then we need to know what choice patterns we predict for these more difficult situations. We need to know (a) what should be the upper limit on the amount of risk that a person can afford or assume, (b) what predictions would a risk-sensitive model of human choice make when the distance between the expected mean and minimum requirement is beyond the range of the mean plus variance, and (c) given different risk distributions, what are the optimal risk strategies? And last but not least, how do people set their minimum requirement or aspiration level according to content, context, probability, expected value, and many other social and cultural variables? If one applies a functionally normative model to study human decision making, predictions from the normative model should be clear and unambiguous.

In many cases, however, the finding (Wang, 1996a, 1996b; Wang & Johnston, 1995) that a framing effect only occurs in evolutionarily novel social contexts raises the interesting question regarding the issue of task domain specificity or modularity in social reasoning and decision making. That is, what would happen when the decision cues designed to activate a module are absent or an evolutionarily default context has undergone dramatic changes? In such a situation, does an information-processing module open itself to a more general, "higher" level process for further analysis? If so, in the case of the framing effect found in large-group contexts, a domain-general semantic analysis might be involved.

On a more general level, it is not even exactly clear how we should determine and define a module (or domain specificity) and the way modules are defined is crucial for predictions about how evolved mechanisms are applied to modern environments and to new problems. Assuming a strictly domain-specific model, one might expect that modern problems or tasks that our Pleistocene ancestors did not face must be solved either by a general-purpose mechanism or by mechanisms co-opted from modules that originally served a different purpose. On the other hand, accepting higher order modules or modules that look for specific structures inherent in a problem rather than being content dependent might imply that these evolved mechanisms continue to be applied in the modern world with new problems as well. To make bold and testable predictions of human behavior, we have to define to which problems evolutionary psychology applies. This, however, requires further clarification of our understanding of the architecture of the human mind.

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