Mapping Biases to the Components of Rationalistic and Naturalistic Decision Making

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People often create and use shortcuts or "rules of thumb" to make decisions. The majority of time, reliance on these heuristics helps us to perform efficiently and effectively. Yet, this reliance can also promote bias, or systematic error. Our review of the literature suggests that both decision-making approaches that are rational and natural are likely to be subject to a range of biases. Unfortunately, the available literature provides very little discussion of what aspects biases are likely to impact within each of these processes. In the absence of this discussion, we have attempted to combine our knowledge of the bias literature and the decision-making literature to explore what biases are likely to impact various components of each decision-making process. Includes the following biases: availability, representativeness, anchoring & adjustment, confirmation, hindsight, overconfidence, framing and affect.

HEURISTICS AND BIASES

The formal study of heuristics and biases is commonly defined to have started with the seminal psychological research by Tversky and Kahneman (1974). Since that time, much research into heuristics and biases has been conducted. Over this same time period, advancements have been made in decision-making research, mostly focused in rational and naturalistic decision-making approaches. Yet, little research explicitly maps biases onto both rational and naturalistic decision making components to better understand their effects. That is the goal of this research (Adams et al, 2009).

The term "bias" is often used in tandem with the term "heuristics". Psychological research has shown that people use heuristics to simplify their environments. For example, people may create and use a shortcut or a "rule of thumb" in order to make a decision. Simon (1990; as cited in Shah and Oppenheimer, 2008) declares that heuristics are "methods for arriving at satisfactory solutions with modest amounts of computations" suggesting that people seek to reduce the effort associated with decision processes (Simon, 1990; cited in Shah and Oppenheimer, 2008, p. 207). These shortcuts may involve, for example, relying on known (rather than unknown) sources of information, or using rough gauges rather than established sources of information. Heuristics help to simplify our environment and aid the decision-making process. The majority of time, reliance on these heuristics helps us to perform most efficiently and typically effectively. Yet, this reliance can also promote bias.

A variety of definitions exist for 'bias'. Arnott (2002, p. 4) describes human biases as "predictable deviations from rationality." According to Merriam-Webster, bias can be defined as "an inclination of temperament or outlook; especially a personal and sometimes unreasoned judgment." There is some sense that human decision-making biases simply represent failures to make optimal decisions in all situations. There is a large body of literature showing that people are prone to making a range of errors when working in complex environments. The primary distinction of biases from other types of errors is that human decision-making biases represent systematic rather than random errors – making biases somewhat predictable (Gilovich, Griffin & Kahneman, 2002). The key to biases, then, requires understanding why people are prone to select or "encourage" one outcome or answer over another.

The most prominent biases (and associated heuristics) are described below. It is worth noting that all these biases are closely related, and that they are likely to significantly overlap in definition and effect (Arnott, 2002).

Types of Biases

Availability Bias. The availability heuristic is said to be used when "…an event is judged to be more likely or frequent if it is easy to imagine or recall relevant instances" (Slovic, Fischhoff and Lichtenstein, 1977, p. 4). Information that is more salient or easier to recall (e.g., can be easily retrieved) is used when making judgements about the frequency or likelihood of an event occurring. Tversky and Kahneman (1973, p. 210) argue that relying on the salience and/or availability of an object or event makes sense because "…in general, frequent events are easier to recall or imagine than infrequent ones". The bias arises when factors unrelated to the actual frequency or probability of an object or event can influence our estimates. These factors include familiarity, recency and emotional saliency. For example, we are more likely to think that plane crashes are frequent occurrences after a plane crash has been widely reported in the media.

Representativeness Bias. The representativeness heuristic occurs when we classify something or someone according to its similarity to a typical case. Objects, events or processes are assigned to one conceptual category based on how well they represent or resemble one category over another category (Nisbett & Ross, 1980; as cited in Jones, 2005). Using the representative heuristic is natural because it simplifies decision-making and eliminates the need to "reconstrue" each new situation. The problem, however, is that pre-existing templates are not necessarily accurate in each new situation, and this can lead to systematic errors (Tatarka, 2002) when a suboptimal category is used to make a decision. For example, a military display operator may be inclined to disregard a target that shared some characteristics of commonly benign targets. This could lead to a decision error.

Anchoring and Adjustment Bias. We often make guesses by picking a natural starting point (an anchor) for a first approximation and then adjust our guesses until we reach a final estimate. This can be a very useful technique for making estimates, as long as people properly adjust from the anchor (Gilovich et al., 2002; as cited in Jones, 2005). Biases arise when our estimates and decisions are overly influenced by the initial values or starting points that we use as anchors. In these cases, we do not adjust our estimates (and subsequent decision) as much as we should after receiving new information (Jones, 2005). Thus, our final estimate will be biased in the direction of the initial anchor (e.g., may be closer to the anchor than it should be).

Confirmation Bias. Confirmation bias is defined as the human tendency to see what we expect, need, and/or want to see from our environment. Confirmation bias makes us more likely to seek information and cues to confirm our own hypotheses, rather than seek information to disprove such hypotheses (Chia, 2005). Factors such as time pressure can lower this threshold level (Dror & Fraser-Mackenzie, 2008), and make confirmation biases even more likely. Our tendency to understand information in ways that support our own hypotheses can result in a "cognitive tunnel vision" (Chia, 2005). When we have this tunnel vision, we tend to ignore contradictory or inconsistent information, often to the detriment of the decisions that we make.

Hindsight Bias. Colloquially applied through the phrase 'hindsight is 20/20', the hindsight bias is one of the most pervasive in the available literature. Put more simply, it refers to the fact that when people have prior information about the actual outcome, they are more likely to overestimate the probability that they would have predicted the outcome than without this prior information.

Overconfidence Bias. Being overconfident in our own judgments, skills and decisions is a ubiquitous human bias. Overconfidence happens when we assume that our abilities, perceptions and beliefs are more "correct" or more positive than they actually are. As such, after making decisions, decision makers consistently over-estimate how correct those decisions are. For example, studies have shown that even when participants taking a test think their answers to be absolutely correct, they are generally wrong 20% of the time (Koriat et al., 1980).

Framing Effects. How problems are framed influences how humans make decisions about them. This phenomenon has been studied in detail. Take for example following disease problem (Tversky and Kahneman, 1981):

> "Imagine that the United States is preparing for the outbreak of an unusual disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. If Program A is adopted, 200 people will be saved. If Program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved. Which one of the two programs would you favor?"

When presented with this problem, most respondents favor A (risk aversion). Alternatively, if participants are given the same scenario with a different frame, they often make a different decision:

> If Program A is adopted, 400 people will die. If Program B is adopted, there is a one-third probability that nobody will die and a two-thirds probability that 600 people will die.

With this frame, then the majority of people tend to favor Program B (risk seeking). This suggests that people can be more risk averse or risk-seeking even though they are asked substantially the same question with only a somewhat different frame. This has also been shown in real-world healthcare examples, with framing effects contributing to different judgements, depending on whether statistics are shared in terms of survival rates or mortality rates.

Affect Bias. There is good evidence in the psychological literature that peoples' emotional responses to an object or situation (rather than the objective characteristics of the situation) can influence their decision-making processes. In short, when making decisions, people sometimes use their current emotional state in order to assist their judgment processes. This is evidence of reliance on the affect heuristic. The feelings-as-information hypothesis has been studied specifically. It is based on the "assumption that feelings can serve as a source of information in their own right" (Schwarz & Clore, 2003, p 1). This hypothesis argues that people use their emotional state as a source of information when making decisions.

Statistical Bias. Sub-optimal decisions are often made due to statistical biases. Deducing errors in statistical estimates is done by comparing peoples' responses to Bayes theorem (or Bayes law). Bayes theorem suggests that optimal reasoning can be achieved by using established "prior probabilities" when making judgements about the frequency or probability of events (Yudkowsky, 2003). To the extent that we can know the likelihood of a given event occurring, then, when we are required to make judgements about this event, we should logically use the established probability. However, a wide range of research suggests that people often fail to use proper statistical reasoning, either by ignoring prior probabilities, or selectively focusing on one atypical incident to guide their actions rather than relying on more typical probabilities.

Now with an understanding of the prominent biases in the literature, our focus shifts to models and approaches toward decision-making.

DECISION MAKING APPROACHES AND BIASES

Two philosophically different approaches to decision-making are commonly identified in the literature (e.g., Azuma, Daily and Furmanski, 2006). The first approach, the rational decision-making model (aka logical or analytical), focuses on the outcome of the decision. The second approach, naturalistic decision-making, focuses on the process of decision-making rather than on the outcome of decision-making (Azuma, Daily and Furmanski, 2006). A closer look at both of these approaches is required to map biases to the components of each of these approaches.

Rational Decision Making and Biases

Proponents of the rational decision-making approach assume that when making decisions, a clear set of alternate choices can be generated, that the underlying information used to make decisions is reliable, and that one can reliably predict the outcome of their decisions. When using this model, criteria are established for making decisions and the information is weighed in order to make the "best" decisions; hopefully making an objective decision. While experience will improve and speed up decision making, this approach can also be applied by novices to arrive at suitable decisions. By their very nature, then, rational decision-making approaches seem best applied to domains where "the goals are well defined, the environment changes slowly and no other active agents are present" (Grant, 2009, p. 2).

A number of potentially problematic assumptions of rational choice models have been pointed out (e.g., Bryant, Webb, & McCann, 2003; Orasanu & Martin, 1998). The goal of decision-making using rational models is typically to make the best decision, which assumes that there is one optimal decision. In complex situations, determining what the "optimal" decision is can be challenging, For example, the relationship between a discrete decision and its outcome can be difficult to understand (Orasanu & Martin, 1998). Outcomes cannot necessarily be used as reliable indicators of the quality of the decision made. That is, uncontrollable events can result in undesirable outcomes even if a good decision is made (and vice versa).

Rational choice theories also require the decision maker to compare decision alternatives, which assumes that all factors related to the decision can be identified and quantified in terms of importance. Rational models further assert that decision makers are able to generate all possible options for a situation from which they can choose the optimal solution. In any case, rational models demand following strict procedures, or axioms, in order to foster optimum decisions. In reality, however, there is some agreement in the literature that rational processes are not always followed in complex environments.

Our review of the literature suggests that both rational approaches and naturalistic approaches (as discussed below) are likely to be subject to a range of human decision-making errors and biases. In general, biases associated with intuitive or naturalistic approaches have been the most systematically explored, because rational decision-making approaches generally assume that people will be accurate provided that they have the right type and amount of information. Proponents of the rational processes argue that any errors that do occur are unsystematic (Gilovich, Griffin and Kahneman, 2002). The fact that biases and errors are systematic, of course, is an assumption of the heuristics and biases approach. Rational proponents tend to view decision error as the result of the decision maker's knowledge base or the result of the process used to reach the decision (Orasanu & Martin, 1998), but fail to acknowledge that humans are intrinsically subject to decision-making biases.

In order to synthesize the decision-making and biases information in a meaningful way, we worked to understand the general effects of errors and biases within a more analytic decision-making process. In general, conventional analytic decision-making is often understood in terms of the following phases:

Search. Searching and gathering relevant information. This stage includes determining where to look for information

Attend. Determining what kind of attention to give the information and where to focus attention.

Weight. Weighting criteria and estimating outcomes. For example, in military decision-making, if making a judgement about the pros and cons of attacking one's adversary, it would be important to decide how to weight often discrepant pieces of intelligence information. Some information, for example, may show a build-up of their troops along a critical corridor and another piece of information may show their leaders taking a conciliatory stance in negotiations. The key, then, is the weight given to these pieces of information.

Combine. Combining information together through to give some broader form of meaning. In essence, this requires working to create some sort of "story" about what the many different "pieces" of information actually present. The decision-making literature suggests, for example, that having a coherent narrative structure can aid decision-making processes.

Interpret. Understanding causal relationships and making a decision.

Our analysis suggests that each of the conventional elements of rational decision-making are also uniquely susceptible to specific decision-making biases (Table 1).

Table 1. Biases in rational decision-making components

	Search	Attend	Weight	Combine	Interpret
Availability	✓	✓		✓	✓
Representativeness	✓	✓		✓	✓
Anchoring and adjustment	✓	✓		✓	✓
Confirmation bias	✓	✓		✓	✓
Hindsight					✓
Over-confidence			✓		✓
Statistical biases			✓	✓	
Framing Effects	✓	✓	✓		
Affect heuristic	✓	✓		✓	✓

This grid shows that availability and representativeness biases and anchoring and adjustment biases are potentially relevant at all but the weighting stage of decision-making. For example, due to one's pre-existing beliefs and attitudes, one can easily overlook contradictory information after it is perceived (i.e., at the "attending" stage) or even fail re-interpret this information to be congruent with one's desired world view (i.e., when interpreting the information). Confirmation bias involves "situating" on a specific dimension. Affect-related biases are most relevant at the perception (searching and attention stages) of decision-making, but could also have impact at later stages. Framing effects impact what information is searched, attended to and weighted.

Other biases typically have a somewhat more constrained impact on the decision-making process by their nature. Hindsight biases involve working retrospectively to understand why events occurred as they did, whereas overconfidence primarily involves an inaccurate weighting of the pros and cons of a situation in one's favour and/or being unrealistic about one's probability of success in a given situation, as well as self-serving interpretations.

A similar biases mapping was also done for NDM.

Naturalistic Decision Making and Biases

The naturalistic decision-making approach assumes that there is not necessarily an ideal or optimal solution to a problem, but that the best approach will be determined by a number of factors not typically considered in rationalistic approaches. By utilizing a satisficing strategy, i.e. finding a 'good enough' solution (Simon, 1960; as cited in Guitouni et al, 2006) – as opposed to an optimization strategy – suitable solutions are usually implemented (Klein and Calderwood, 1989). Moreover, proponents of this approach assume that too much information can be detrimental to our ability to make a decision and that we can never fully quantify a situation in order to come up with a mathematical solution. This type of decision-making is often referred to as descriptive because it describes how we normally think, rather than how we should think (prescriptive).

Naturalistic decision-making approaches (NDM) are noted for their emphasis on the role of expertise. NDM researchers hold that “many important decisions are made by people with domain experience and, therefore, that it is important to learn how people use their experience to make these decisions” (Pliske & Klein 2003, p. 561). Experts are acknowledged to be able to use “shortcuts” to reach high quality decisions, because their expertise enables them to recognize adequate solutions to the issues that they face. NDM approaches are also particularly well suited to complex, dynamic decision-making environments. High levels of uncertainty, incomplete information, time pressure, and unclear goals pull for decision processes that are more efficient and take less time than analytic decision-making processes.

The information requirements within the NDM approach are also more constrained. While analytic approaches require the generation and weighting of all available options, the NDM approach simply requires that the decision maker is able to form an adequate “picture” of the current situation, and to be able to access analogies of situations faced in their previous experience. If they are able to find a simple match, the decision process is complete, and other options and COAs need not even be considered. If not, more deliberation is necessary, but the length of this NDM process falls far short of that required for analytic decision-making.

One of the most important features of naturalistic decision-making is that it strives for a satisfactory solution rather than an optimal solution. If a very quick but adequate decision can be made, the NDM process can be declared complete without further attention. This, of course, is quite distinct from the analytic process, wherein all alternatives need to be systematically considered even though the decision maker might intuit a faster solution.

Of course, NDM approaches have both strengths and weaknesses. Key strengths include maximal use of experience and expertise, and quick and efficient completion of the decision-making process. On the negative side, however, NDM approaches have also been criticized because they do not require a full analysis of the available options. This could lead to a decision maker overlooking an excellent solution that they would have considered if they had taken the time to consider all the alternatives. Moreover, the NDM approach does not emphasize full consideration of all possible outcomes of one’s decision, so could result in unexpected surprises if the experiential analogy being used does not reflect the current outcome. Killion (2000) also notes the potential “garden path” risk when using NDM approaches, namely that one’s assumptions about the best match in a given situation could be wrong, and decisions based on those assumptions could be faulty. Another potential limitation is that experts are not necessarily available in every situation. When this is the case, it is unclear that the approach provides an adequate basis through which novices would be able to make optimal decisions. As Bryant (2004) has noted, even though naturalistic decision-making approaches describe a broad range of important processes (e.g., recognition, pattern matching), it fails to adequately explain exactly how people actually undertake these processes. Nonetheless, naturalistic decision-making approaches have been extremely influential within a range of environments.

Naturalistic decision-making approaches, of course, are also subject to human decision-making biases and errors. Although these processes require some generic decision-making processes also relevant to rational decision-making (e.g., searching and attending), they emphasize other unique aspects of decision-making. Four processes related to naturalistic approaches are situation assessment, pattern matching, story generation and mental simulation. Unfortunately, the available literature provides very little discussion of what exact biases are likely to impact each of these processes. In the absence of this discussion, we have attempted to combine our knowledge of the bias literature and the decision-making literature in order to explore what biases are most likely in each of these naturalistic processes. Decision-making biases could occur in each of these different processes, as shown in Table 2.

Table 2. Biases in naturalistic decision-making components

	Situation assessment	Pattern matching	Story generation	Mental simulation
Availability	✓	✓	✓	
Representative-ness	✓	✓	✓	✓
Anchoring and adjustment			✓	✓
Confirmation bias	✓	✓		✓
Hindsight				✓
Over-confidence	✓		✓	✓
Statistical Bias		✓		✓
Framing Effects	✓	✓		
Affect	✓		✓	✓

Situation assessment involves processing information from the environment as a basis for one’s decision. This process could be affected by availability biases – as information that is more accessible in some way could be given more emphasis. Similarly, new information gained during the SA process could also be interpreted as fitting in known categories (representative bias) when it actually does not. The process of pattern matching involves pairing a new event or new object with one’s experience and/or expertise. Having solved a past problem in a particular way, then, one might be more inclined to mistakenly assume that a new problem has the same characteristics and that it could be solved the same way; even though it has characteristics that are not consistent.

Story generation and mental simulation are also amenable to biases. Story generation involves building a coherent picture of the problem. As such, it involves joining information together, and working to construct a meaningful interpretation of the situation at hand. Lastly, the process of evaluating the mental simulation that one has created (i.e., imagining how the situation might unfold in one’s head) is also subject to similar biases.

DISCUSSION

In conducting our in-depth research into decision-making biases, and rational and naturalistic decision-making approaches, mapping the biases onto the components of decision making was a necessary task. Despite the quantity of research into these prominent biases and decision-making approaches, there was a surprising lack of integration of these areas in this respect.

Measures to eliminate biases – commonly called debiasing (Fischhoff, 1982) – have been widely studied, but broadly effective techniques have generally *not* been discovered. This means that efforts to increase bias awareness, warn decision makers, provide decision feedback, improve training, increase decision maker incentives and motivation have all had limited effectiveness (Arnott, 2002; Fischhoff, 1982; George, Duffy and Ahuja, 2000; Koriat, et al., 1980; Lehner et al., 1997; Kunda, 2002; Ward, 2000, Woocher, 2008). Perhaps the reason bias solutions have not been broadly effective is because these techniques only affect one aspect of decision-making as opposed to affecting the entire decision (e.g. efforts to eliminate statistical biases may only impact on the 'weight' phase but not the 'combine' phase during rational decision making). The authors postulate that focusing on a single component of decision-making for a particular bias may lead to more effective debiasing techniques.

Building on this concept, a bias that maps to fewer decision-making components should be easier to mitigate. Indeed, hindsight bias – the least mapped bias in both the rational and naturalistic approaches – is one of the few biases that shows some means of reduction through contradictory thinking. Other biases that have also been shown to be mitigated through contradictory thinking include confirmation, and overconfidence biases. These three biases all affect the 'interpret' component of rationalistic decision-making and the 'mental simulation' component of naturalistic decision making suggesting that it is these specific components/phases of decision-making that is affected by counterfactual thinking. While this is a logical induction, much more extensive research into this theory, the components and the mappings is required, perhaps via experimentation. It is hoped that through a more structured understanding of the ways in which various biases affect different phases of decision making, decision makers can better understand their own decision-making processes and systems designers can better implement design solutions to overcome biases.

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