Rational decision-making

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Introduction

Human decision-making has received a lot of bad press. The Enlightenment ideal of human rationality has been challenged by 50 years’ worth of research showing that people’s choices do not conform to the normative models of classic decision theory (Samuelson, 1937; Tversky & Kahneman, 1981; Von Neumann & Morgenstern, 1944). Indeed, the 2017 Nobel Prize for Economics was won by Richard Thaler for work on the irrationality of human decision-making; this joins the 2002 prize awarded to Daniel Kahneman, who along with Amos Tversky has done more than anyone else to advocate the idea that human judgment and decision-making is biased and inconsistent. These ideas have entered the public consciousness via a wealth of TV programmes, magazine articles, and books with titles such as Predictably Irrational (Ariely, 2008).

The conventional view of such irrationality is that, because human processing capacity is limited, there is an inevitable trade-off between the quality of a decision and the time or effort that goes into it. Many researchers argue that there are ‘two systems’ for judgments and decision-making, one which makes rapid, ‘intuitive’ responses based on superficial processing of information, and another that makes careful, deliberative evaluations that are more accurate but effortful and time-consuming (e.g., Morewedge & Kahneman, 2010; Petty & Cacioppo, 1986; Stanovich & West, 2000). Kahneman’s (2011) popular-science book Thinking, Fast and Slow embodies this idea in its very title.

Here, we articulate a different view based on recent empirical work and conceptual analysis. We survey three famous instances of conventionally irrational decision-making, and show how, in each case, the supposed irrationality assumes a very different complexion once one takes into account the information available to the decision-maker at the time of choice.

Loss-gain framing: Option-descriptions as a source of information

Conventional rationality posits *descriptional invariance*: one’s evaluation of an option should not depend on how it is described or “framed”. However, human decision makers often violate this fundamental axiom. The most famous illustration is Tversky and Kahneman’s (1981) ‘Disease Problem’. Participants are told that an unusual disease is expected to kill 600 US citizens, with two courses of action available. In a positive-framing condition (or ‘gain frame’), participants are told:
If program A is adopted, 200 people will be saved. If program B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability than no people will be saved.

In a negative-framing condition (or ‘loss frame’), participants are told:

If program C is adopted, 400 people will die. If program D is adopted, there is 1/3 probability that nobody will die, and 2/3 probability than 600 people will die.

Now, program C is simply an alternative description of program A, and program D is a reframing of program B. However, 72 per cent of people chose A over B, but 78 per cent chose D over C. That is, people’s preferences reversed merely because the end states were expressed as gains (lives saved) or losses (lives lost). This result has been replicated many times, including for monetary gambles (e.g., Tombu and Mandel, 2015).

This loss-gain framing is a cornerstone of Prospect Theory (Kahneman & Tversky, 1979), the most famous descriptive account of decision under risk. According to Prospect Theory, decision makers evaluate outcomes as changes from a reference point, which is usually the status quo. Objective values are transformed into subjective values via a power function, such that people show diminishing sensitivity to gains (winning £200 is not twice as good as winning £100) and to losses (losing £200 is not twice as bad as losing £100).

According to this framework, people prefer Program A over Program B because the subjective value of gaining (i.e., saving) 600 lives is not three times that of saving 200 lives, so the risky option (a one-in-three chance of saving 600 people) is not attractive. In contrast, program D is preferred to program C because the negative subjective value of losing 400 people is more than 2/3 that of losing all 600 people, so the risky option seems attractive. (Prospect theory also posits that each outcome is weighted according to its probability of occurrence, with over-weighting of rare events and under-weighting of very probable outcomes. This component of the model is not important for our discussion.)

Prospect theory has a number of flaws (see e.g., Birnbaum, 2008). In particular, although Prospect Theory describes patterns of choice, it makes no claims about the specific mental operations involved, whereas more recent models have sought to how information is processed within each decision (e.g., Stewart et al., 2016). A related issue is that, contrary
to the stable value function posited by Prospect theory, people’s actual valuations of outcomes are highly sensitive to other, recently encountered values (Walasek & Stewart, 2015).

For our purposes, however, a key insight concerns the role of inference in the loss-gain framing effect. Look again at the descriptions of Programs A, B, C, and D. You’ll notice that the descriptions are somewhat incomplete. For example, Program A states that 200 will be saved, but says nothing about the number that will die, whereas program B articulates two ‘branches’, one where some people are saved and another where some people die – although again, neither branch states what would happen to the remaining individuals.

It turns out that the explication of the response options exerts a sizeable effect on people’s choices in this task. For example, Kühberger (1995) found that, with the conventional version of the Disease Problem, 46 per cent of people selected the risky option in the gain-frame whereas 70 per cent did so in the loss frame; this replicates the classic pattern. However, Kühberger also tested a novel variant of the task, in which the sure options were fully described (e.g., ‘If program A is adopted, 200 people will be saved and 400 people will not be saved’). Now 47 per cent chose the risky option in the gain frame and 52 per cent did so in the loss frame -- the framing effect disappeared.

Similarly, Mandel (2001) truncated the certain options (e.g., replacing the original ‘a 1/3 probability that 200 will be saved and a 2/3 probability that no people will be saved’ with simply ‘a 1/3 probability that 200 will be saved’). Again, this manipulation eliminated the framing effect. Indeed, Mandel (2014, Experiment 3) took this one step further, by presenting the fully-explicated versions of the sure-thing outcomes (e.g., ‘200 will be saved and 400 will not be saved’) with the truncated versions of the risky options (e.g., ‘one-third probability that 600 will be saved’). In this study, there was a reversal of the normal framing effect, with 68 per cent choosing the risky option in the gain frame but only 42 per cent doing so in the loss frame.

One interpretation of these findings is that, akin to the distinction between ‘intuition’ and ‘deliberation’, decision-makers may represent outcomes in two ways: as a precise value, and as a simplified ‘gist’ (Reyna & Brainerd, 1991). An alternative view is that these results speak to the role of inference in decision-making. At its most basic, this idea encapsulates the fact that our everyday use of phrases such as ‘200 people will be saved’ may not correspond to the intentions of the researcher who
poses people with decision-making problems. For example, Mandel (2014) demonstrated that, with the conventional explication of the certain option, the majority of participants (64 per cent) interpreted the certain options to mean ‘at least X will be saved/die’ rather than ‘exactly X will be saved/die’, whereas the most common interpretation of the risky options was that the outcomes were exact. Given such an interpretation, preference reversal between the two frames is rational: faced with the choice between at least 200 people being saved and a precisely one-third chance of all 600 being saved, the sure-thing is the better option. Conversely, faced with at least 400 deaths versus precisely two-third chance of 600 people dying, the gamble maximizes expected value.

More broadly, decision-makers may reasonably take the wording of the problem to convey hidden information about the value of each option. Why, for example, would the problem-setter choose to phrase an option as ‘saving 200 people’ rather than ‘killing 400 people’? Presumably because he or she has some additional reason for thinking that this option is a good one. That is, while two frames may be logically equivalent, they need not be ‘informationally equivalent’ (McKenzie, 2004). Consistent with this, Sher & McKenzie (2008) asked people how they would describe the Disease Problem options to others and found that those who favoured the sure-thing option were more likely to state it in terms of ‘lives saved’ than were those who preferred the risky option.

To summarize: loss-gain framing is an archetypal demonstration of irrational choice, but a closer inspection suggests that it may reflect the rational use of the information available to the decision-maker. People may interpret the description of options differently from how the problem-setter intends, but reason consistently thereafter; equally, people may use the wording of response options as a source of information about the optimal course of action. The extent to which such processes are necessary or sufficient to explain framing effects, and the precise mechanisms in play, remain a subject of debate (e.g., Chick et al., 2016; Tombu & Mandel, 2015).

The gambler’s fallacy: Reasonable predictions based on finite memory

Our next example concerns people’s predictions about random outcomes. The archetype of this kind of decision involves betting on the outcome of a coin flip, and a key finding is that, although each coin toss is independent of the last, people commonly commit the gambler’s fallacy, where a run of heads leads to the belief that the next outcome will be tails (or vice-versa). This pattern is seen in simple laboratory tasks
with sequences of random events such as light flashes (e.g., Tune, 1964), in pen-and-paper exercises (e.g., Matthews, 2010), and in real-world decision environments. For example, Croson and Sundali (2005) analysed casino bets and found that increasing streaks of one binary outcome on the roulette wheel (e.g., a run of red) led to increasing values of bets against that outcome on the next spin. Similarly, Hardman (2009) cites a news story in which players of the Venetian lottery were driven to increasingly extreme betting (and in some cases financial ruin) by the non-appearance of the number 53 for two years.

The most widely-repeated explanation for this behaviour invokes the *representativeness heuristic* (Kahneman & Tversky, 1972), the core idea of which is that probability judgments are often based on an assessment of similarity. In the case of the gambler’s fallacy, a sequence is presumed to be judged improbable if its statistical properties are dissimilar to the decision-maker’s prototype for the data-generating process. For example, people know that a coin will, in the long run, come up heads and tails equally often, and therefore judge a run of heads to be unlikely because this local sequence deviates from their prototype. Kahneman and Tversky (1972) provided indirect evidence for this by presenting people with scenarios such as:

‘All families of 6 children in a city were surveyed. In 72 families the exact order of births of boys and girls was GBGBBG. What is your estimate of the number of families surveyed in which the exact order of births was BGBBBB?’ (p. 432).

Statistically, both sequences are about equally likely, but 75 out of 92 participants judged GBGBBG to be more likely than BGBBBB, which Kahneman and Tversky attribute to the fact that the former has the 50-50 boy-girl proportions as approximately exist in the population. Likewise, participants judged BBBGGG to be less likely than GBBGBG; again, both are similarly probable, but the former deviates from our prototype that a random sequence is one in which the outcomes alternate.

More recent work has challenged this approach. In addition to the heuristic being under-specified (how do we establish a person’s prototype for a particular type of sequence or process? And how do people assess similarity or ‘representativeness’?), researchers have typically not directly tested whether people are actually using similarity-to-prototype as the basis for their decisions; correspondingly, the ‘explanation’ is arguably just a description of the data (Gigerenzer, 1996). Indeed, the representativeness heuristic been invoked to explain behaviour which is
the diametric opposite of the gambler’s fallacy – namely, the hot hand fallacy, in which a decision-maker takes a run of success at a task to indicate that subsequent success is more likely, even when it is not (for example, a gambler who believes that a run of wins on roulette means that they should bet more on the next spin; see e.g., Gilovich, Vallone and Tversky, 1985). The fact that the same heuristic has been invoked to account for two opposing patterns of behaviour indicates that it lacks value as a scientific explanation (see Ayton & Fischer, 2004; Burns & Corpus, 2004).

An alternative approach posits that the gambler’s and hot hand fallacies arise from the mis-application of principles that legitimately described the behaviour of certain kinds of stochastic process. In particular, many random processes involving the physical world can be conceptualized as sampling without replacement. A simple example would be foraging for food: if a tree offers a mixture of good and bad apples then the more good apples one picks, the higher the chance that the next one will be bad, and the belief that a run of one outcome increases the chances of the other is accurate. The gambler’s fallacy may reflect generalization of this principle to a class of systems that behave as if one is sampling with replacement, and such systems are relatively rare in the natural world. Conversely, belief in the hot hand can be seen as a generalization of the principle that many types of human performance really do show positive recency: people get better with practice, or worse as they become gradually more fatigued. A gambler who takes a run of three wins to indicate that ‘their luck is in’ may be generalizing a principle that, in many situations, would be correct. Consistent with these ideas, Ayton and Fischer (2004) demonstrated that sequences with a high alternation rate (i.e., which frequently flip back and forth between two outcomes) were inferred to be generated by a mechanical process such as a coin flip, whereas those with a low alternation rate (long runs of one outcome) were judged to be produced by skilled human performance (such as basketball shots) (see also Matthews, 2013).

The inappropriate generalization account and the representativeness heuristic share the principle that the gambler’s fallacy arises from the application of a strategy that normally works well but which is not appropriate for this specific situation. Recent work, however, suggests a different basis for the effect. Specifically, Hahn and Warren (2009) show that the gambler’s fallacy might be a reasonable inference given some simple assumptions about human cognition, namely that people have limited memory capacity and only ever see finite sequences of random events. Imagine a sequence of 20 coin flips for which we analyse every
subsequence of length four (a plausible working memory size). The mathematics are such that not all sequences are equally likely any more: runs of four heads are less likely than three heads followed by a tail. Thus, when people use their (finite) memory of (finite) past sequences as the basis for predictions about new sequences, or of judgments about randomness, they will underestimate the probability of observing long runs. According to this account, the longer the sequences that a person has observed in the past, the more likely it is that all possible combinations of heads and tails will have occurred equally often and the less biased they should be – a result recently reported by Farmer, Warren, and Hahn (2017).

To summarize: the gambler’s fallacy illustrates a core truth about rational decision-making: a decision-maker can only be rational about the data that she has available to her, and that information depends on memory. Choices that would be irrational given a perfect memory system may be perfectly rational given the data that can actually be retrieved.

Decoy effects: Rational inference from noisy computation

Our last example concerns the independence of irrelevant alternatives (IIA), a core tenet of rational decision theory. Suppose we offer you the choice between an apple and an orange, and you choose the apple. It would be surprising to learn that, had we offered you the choice between an apple, an orange, and a banana, you would have chosen the orange. Indeed, this kind of inconsistent choice could be very disadvantageous: assuming that you are prepared to pay a small premium to have the option you prefer, and if your preference between A and B reverses depending on whether or not C is presented as an option, then you could be turned into a ‘money pump’. However, there are numerous violations of the IIA principle, such that the preference between two items is affected by the addition of a third, ‘decoy’ option.

An early example comes from Tversky (1972), who had people choose between fictional college applicants with differing intelligence and motivation scores. Faced with student X (intelligence = 78; motivation = 25) and Y (intelligence = 75, motivation = 35), 55.6 per cent chose X. When student Z (with intelligence = 60 and motivation = 90) was added as an option, then people sometimes chose him. More importantly, of those times when they chose either X or Y, they now preferred Y (only 46.3 per cent chose X). This illustrates the similarity effect: Z is similar in both intelligence and motivation to X, and seems to reduce the attractiveness of that candidate (Figure 1.1, top).
Figure 1.1 Context effects. The top panel shows the arrangement of attributes that produces the similarity effect: people preferred X over Z when these were presented in isolation, but the addition of Y means led them to prefer Z. The middle panel illustrates the context that evokes the compromise effect: people are indifferent between B and C, but the addition of D leads to preference for C. The bottom panel illustrates that layout that leads to the attraction effect: a preference for the web-only option over the print-and-web option reverses following the addition of a print-only option that costs the same as the print-and-web package.

A second context effect is illustrated by Simonson (1989), who had people choose between flats differing in their distance and general condition. In a choice between Apartment B, which is far away but in good condition (distance = 11 miles, condition = 90 per cent) and Apartment C, which is close but in worse condition (distance = 6 miles, condition = 75), 50 per cent chose each option. The addition of Apartment D, which is very close but quite run down (distance = 1 mile, condition = 60), 66 per cent of people chose apartment C, which now represents a compromise between the extremes of proximity and condition represented by the other two flats (Figure 1.1, middle).
Perhaps the most famous context effect is the attraction effect (aka the asymmetric dominance effect), in which the decoy option is similar to one of the two focal options, but inferior to it on one or more dimensions (Figure 1.1, bottom). A real-world example is reported by Ariely (2008), who noted that the Economist magazine offered a web subscription for $59, a print-and-web subscription for $125, or print only subscription which was also $125. When Ariely presented people with just the first two options, only 32 per cent chose the print-and-web option. However, when people were given all three options, 84 per cent chose the print-and-web deal.

These effects occur in a wide variety of domains, including choices between risky gambles (Farmer et al., 2017), inference tasks (Trueblood, 2012), and perceptual judgments (Trueblood et al., 2013). They have also been found in non-human species, including bees (Shafir et al., 2002) and slime mould (Latty & Beekman, 2011).

A wide range of mechanisms have been posited to account for these context effects. As examples: Tversky (1972) argued that the similarity effect arises from an elimination-by-aspects strategy, in which the decision maker picks a dimension (e.g., the intelligence of a college applicant), rules out any option which does meet some threshold on that dimension, and then considers the next dimension (e.g., the student’s motivation); Simonson (1989) argued that the compromise effect results from decision-makers looking for options that can readily be justified to other people (one can readily justify the selection of an option that is not extreme on either dimension); and Wedell (1991) has explored whether the attraction effect results from changes in the relative values of the attributes under consideration (e.g., adding the decoy changes the smallest/largest values for one dimension, and correspondingly changes the distance of the other attribute values from the ends of the range). More recently, researchers have developed integrated, information-processing models which capture all three effects in a common framework, and which predict not just the choice proportions but also the distribution of decision-times for each choice set (Roe, Busemeyer & Townsend, 2001; Trueblood, Brown & Heathcote, 2014).

Recently, a completely different perspective has emerged from work that focuses on the function that such effects might serve. In particular, Howes et al. (2016) have shown that, rather than violating rational decision theory, these context effects may reflect a rational use of available information under computational constraints. Just as people do not have perfect memory for random sequences (see the Gambler’s
Fallacy, above), so they are not perfectly able to integrate multiple attributes in order to assess subjective value. For example, consider a risky prospect such as a 19 per cent chance of £73 (otherwise nothing). Computing the subjective value of such an option is difficult: conventional economic theory says that the rational approach is to calculate the expected utility, 0.19*u(73), where u(x) is a utility function that captures the diminishing returns of progressive increases in wealth (i.e., the fact that the subjective value of £200 is not twice that of £100). When faced with two or more risky options, one should then choose the option with higher expected utility. To be clear, it is not suggested that people do, or should, make such calculations explicitly – only that their choices should be as if they have calculated expected utility.

In practice, no organism can be expected to perform such calculations in an error-free fashion. This is not a question of it being hard to do maths: the options under consideration could be objects that present a trade-off of physical attributes (e.g., a small, tasty meal versus a larger, less flavoursome option), but in all such choices, there will be noise in the integration of attribute values that leads to uncertainty about the subjective value of each option.

The core insight of Howes and colleagues is that, faced with such uncertainty, the ordinal relations between attribute values provide a useful source of information about the likely value of the options. For example, consider the (difficult) choice between (A) a 19% chance of winning £73, (B) a 41% chance of winning £23, and (C) a 57% chance of £15. The decision-maker might compute expected values, as described above. Alternatively, she might choose on the basis of the much-less-precise, but also less noisy, ordinal relations between the items (e.g., C offers a better probability than both A and B). However, the best strategy is to combine these two sources of information: by integrating a noisy estimate of expected utility with an estimate based on the ordinal information, people make better choices than they would using either estimate on its own.

Crucially, Howes and colleagues show that combining the two kinds of estimate not only results in better choices, it also produces the similarity, compromise, and attraction effects, because the presence of the decoy options changes the ordinal relations between the items in the choice set.

To summarize: context effects violate conventional rational choice behaviour, but can be seen as the rational use of available information given the decision-makers inevitably-limited computational capacity.
Conclusions

Human decision-making is flawed, but claims about our irrationality are perhaps overstated: people might make rational decisions given the information that’s actually available to them. Once we account for (a) people’s interpretation of the presented options, (b) our finite capacity to remember past data, and (c) the inevitable noise in the integration of value, three of the classic demonstrations of irrational decision-making become considerably less clear-cut. Of course, there are likely to be genuine errors, biases, and inconsistency in human choices, but our survey indicates the importance of considering the informational and computational context before interpreting such effects.

References


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