Cognitive Psychology 93 (2017) 44–73

Contents lists available at ScienceDirect

Cognitive Psychology

journal homepage: www.elsevier.com/locate/cogpsych

How the twain can meet: Prospect theory and models of heuristics in risky choice

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ARTICLE INFO

Article history:
Accepted 8 January 2017

Keywords:
Risky choice
Prospect theory
Theory integration
Heuristics
Cognitive modeling

ABSTRACT

Two influential approaches to modeling choice between risky options are algebraic models (which focus on predicting the overt decisions) and models of heuristics (which are also concerned with capturing the underlying cognitive process). Because they rest on fundamentally different assumptions and algorithms, the two approaches are usually treated as antithetical, or even incommensurable. Drawing on cumulative prospect theory (CPT; Tversky & Kahneman, 1992) as the currently most influential instance of a descriptive algebraic model, we demonstrate how the two modeling traditions can be linked. CPT's algebraic functions characterize choices in terms of psychophysical (diminishing sensitivity to probabilities and outcomes) as well as psychological (risk aversion and loss aversion) constructs. Models of heuristics characterize choices as rooted in simple information-processing principles such as lexicographic and limited search. In computer simulations, we estimated CPT's parameters for choices produced by various heuristics. The resulting CPT parameter profiles portray each of the choice-generating heuristics in psychologically meaningful ways—capturing, for instance, differences in how the heuristics process probability information. Furthermore, CPT parameters can reflect a key property of many heuristics, lexicographic search, and track the environment-dependent behavior of heuristics. Finally, we show, both in an empirical and a model recovery study, how CPT parameter profiles can be used to detect the operation of heuristics. We also address the limits of CPT's ability to capture choices produced by heuristics. Our results highlight an untapped potential of CPT as a measurement tool to characterize the information processing underlying risky choice.

1. Introduction

When in 2002 the Royal Swedish Academy of Sciences awarded Daniel Kahneman the Nobel Prize for Economic Sciences, it lauded two pillars of his joint work with Amos Tversky: prospect theory and the heuristics-and-biases program. Both lines of research investigate how human judgment and decision making systematically deviate from standard assumptions of rationality in economics. Yet there is also a fascinating disconnect between the two lines of research. Kahneman pointed out that when developing prospect theory, their approach "was as conservative as possible. [...] The goal [...] was to assemble the minimal set of modifications of expected utility theory that would provide a descriptive account of [...] choices between simple monetary gambles" (Kahneman & Tversky, 2000, p. x). The theoretical thrust of the heuristics-and-biases

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http://dx.doi.org/10.1016/j.cogpsych.2017.01.001
0010-0285/

program, in contrast, was anything but conservative; in fact, it "revolutionized academic research on human judgment" (Gilovich & Griffin, 2002, p. 1). It did so by proposing that people's judgments under uncertainty do not involve extensive operations, but rest on simple mental processes—heuristic in nature—that curtail information search.

The disconnect between Kahneman and Tversky's prospect theory and their work on heuristics (e.g., Tversky & Kahneman, 1974) echoes a more general trend in research on risk choice, namely the separation between algebraic models and models focused on the actual processes underlying choice (cf. Lopes, 1995). Algebraic models—with prospect theory and its extension, cumulative prospect theory (CPT; Tversky & Kahneman, 1992), being the most prominent instances—focus on the algebraic patterns of people's risk preferences and thus on people's ultimate choices but not on *how* the choices come about. They describe choices in terms of a multiplicative integration of (some function of) probabilities and outcomes, followed by maximization, and are rooted in the concept of mathematical expectation and its application to risky choice, first in terms of expected value theory and then in the early incarnation of expected utility theory (Bernoulli, 1738/1954). Like other algebraic models of risky choice (Birnbaum & Chavez, 1997; Lopes & Oden, 1999), CPT assumes that the evaluation of a risky option can be derived by combining mathematical expectation with a few psychological constructs (e.g., risk aversion, loss aversion, probability weighting), all of which are represented by parameterized functions.

The other approach to modeling risky choice takes Edwards' (1953) question as its starting point: "[H]ow do people actually go about making decisions in gambling situations?" (p. 351). Informed by findings from process analyses (e.g., Lichtenstein, 1965; Payne & Braunstein, 1978) and acknowledging cognition's natural bounds of information and computational capacities (Simon, 1955), models of the choice process have often taken the form of heuristics. Unlike algebraic models, models of heuristics focus on the content (rather than just the result) of choice processes and are explicated in terms of the cognitive operations underlying a decision, such as search, stopping, and integration of information (Gigerenzer, Hertwig, & Pachur, 2011; Payne, Bettman, & Johnson, 1993). Being based on simple principles of information processing, models of heuristics typically forego the integration of probabilities and outcomes and ignore part of the available information (e.g., Payne et al., 1993; Thorngate, 1980; for an overview, see Pleskac, Diederich, & Wallsten, 2015). Models of heuristics for risky choice include the semiorder rule (Luce, 1956), elimination-by-aspects (Tversky, 1969, 1972), the minimax and maximax heuristics (e.g., Coombs, Dawes, & Tversky, 1970), the Pwin heuristic (Payne, 2005), the least-likely and the most-likely heuristics (Thorngate, 1980), the similarity heuristic (Leland, 1998; Rubinstein, 1988), and the priority heuristic (Brandstätter, Gigerenzer, & Hertwig, 2006). Although some of these models of heuristics have been formalized mathematically (e.g., Katsikopoulos & Gigerenzer, 2008; Tversky, 1972), we do not classify them as algebraic models here, thus following Lopes (1995). We refer to algebraic models as those that focus on predicting people's overt choices (regardless of the psychological plausibility of the implied process), whereas models of heuristics also aim to specify how information is searched and when search is stopped.[1]

The two modeling approaches to risky choice exist side by side with little theoretical integration, and they have often been treated as antithetical (e.g., Brandstätter et al., 2006; Payne, 1973; Svenson, 1979). Lopes (1995, p. 177) described this separation thus: "Although one might suppose that [algebraic and process] accounts are alternate ways of describing the same thing—indeed, that one kind of model might eventually be reducible to the other—the approaches have tended to be disjoint." The goal of this article is to investigate to what extent algebraic models and models of heuristics represent alternative ways of describing the same thing—or, at least, related things. We argue that CPT's constructs—such as diminished sensitivity to outcome or probability information, risk aversion, and loss aversion, measured through parameters that govern the shape of CPT's value and weighting functions (see below)—offer a useful framework for characterizing heuristic processing principles. Specifically, we demonstrate how differences in CPT parameters can index the use of different heuristic processes.

To avoid misunderstandings, let us clarify two issues right away. First, our goal is not to render one approach reducible to another (a possibility suggested in the quote from Lopes, 1995). Rather, we aim to work out how two possible but disjointed ways to describing risky choice could be brought together. We thus join forces with others who have contributed to overcome the fragmented state of psychological theory (see Dougherty, Gettys, & Ogden, 1999; Johnson & Meyer, 1984; Juslin, Olsson, & Olsson, 2003; Luan, Schooler, & Gigerenzer, 2011; Pleskac, 2007; Schooler & Hertwig, 2005). In a similar vein, Stewart, Chater, and Brown (2006) have demonstrated how the characteristic shapes of CPT's value and weighting functions can arise from an interaction of simple cognitive comparison processes and particular structures of the environment, namely, the distribution of how frequently gains and losses of different magnitudes occur in the ecology. We complement this work by investigating how CPT's shapes may arise from specific characteristics in the processing principles of heuristics, but without making particular assumptions about the choice ecology. Second, for the purpose of our analysis, we consider the models of heuristics investigated here as stylized descriptions of simple processing principles that may operate to varying degrees, depending on the decision context and the decision maker. We do not claim that any one of them offers a comprehensive and veridical account of risky choice (we turn to empirical tests of models of heuristics in the General Discussion).

In what follows, we review previous work connecting algebraic and heuristic models of decision making, and describe CPT's parametric framework as well as several heuristics for risky choice proposed in the literature. We then discuss how choices generated by several heuristics assuming substantially different processes may be reflected in the parameters of

[1] Some of the models of heuristic investigated in our analyses, such as the minimax heuristic, were not originally proposed as process models (Savage, 1954/1972). However, for all models of heuristics, it is straightforward to derive predictions of how information is searched, when search is stopped, and how the choice is made based on the information—our key criteria for whether a model constitutes a process model.