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Original Article

Insights from quantum cognitive models for organizational decision making

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ABSTRACT

Organizational decision making is often explored with theories from the heuristics and biases research program, which have demonstrated great value as descriptions of how people in organizations make decisions. Nevertheless, rational analysis and classical probability theory are still seen by many as the best accounts of how decisions *should* be made and classical probability theory is the preferred framework for cognitive modeling for many researchers. The focus of this work is quantum probability theory, an alternative probabilistic framework. Results in decision making, which appear paradoxical from a perspective of classical probability theory, may make perfect sense if one adopts quantum probability theory. We review some cognitive models of decision making based on quantum probability theory. Each of these models is based on a challenge to prescription from classical probability theory. The transition from labeling a particular behavior as irrational, by classical probability standards, to (potentially) rational (or, at any rate, not fallacious), raises interesting possibilities, including that of characterizing certain heuristics in formal, probabilistic terms.

1. Introduction

In psychology, the classical rational model of decision making assumes that decision makers comprehensively define a problem, understand all possible alternatives and their consequences, and select the very best action after evaluating all the available options (e.g., Anderson, 1991; March, 1997; Simon, 1979). Moreover, all probabilistic computations are assumed to be carried out in a way which conforms to the prescription from classical probability (CP) theory. The link between rationality and CP theory can be justified in important a priori ways, such as the Dutch Book argument (e.g., Howson & Urbach, 1993), which shows that CP reasoning is consistent/coherent, in a certain formal sense (Oaksford & Chater, 2009; Tenenbaum, Kemp, Griffiths, & Goodman, 2011).

Yet many researchers have questioned the relevance of the classical rational model and CP theory in modeling human decision making, especially in the case of applied decision making situations (see also, e.g., Wakker, 2010, for arguments relating to risk and loss aversion). The focus of the present article is organizational decision making. In such cases, decision makers are often assumed to have limited cognitive resources and are faced with environments which are uncertain, complex, and go beyond the assumptions and manipulations of laboratory-based decision tasks. As a result, it has been argued that decision makers operate within the limits of 'bounded rationality', frequently 'satisficing' by making good enough decisions (Simon, 1955) and adapting to their environment by using heuristics and intuition, which can both enhance (e.g., Gigerenzer & Todd, 1999; Gigerenzer, 1991; Klein, 1998) and bias decision making (e.g., Kahneman & Tversky, 1996; Kahneman, Slovic, & Tversky, 1982). Moreover, working in complicated, often emotionally charged, organizational systems, decision makers have to respond to the needs of multiple stakeholders, who can politically influence the decision making process (e.g., Cyert & March, 1963; March & Simon, 1958; Pfeffer, 1981) and both influence and are influenced by the context and the situated, embodied aspects of cognition, in which the decision is being made (e.g., Niedenthal, Barsalou, Winkielman, Karuth-Gruber, & Ric, 2005; Weick, 1995; Wheeler, 2005).

All these are considerations which undermine the descriptive adequacy of CP theory decision making models and the rational analysis approach, in situations of applied decision making. Be that as it may, for many researchers, rational analysis still provides the

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prescription for how decision makers *should* reason, on the basis of the available information. We think this normative aspect of prescription from CP models in a given situation is particularly significant, especially in the case of applied decision making, where, clearly, there is an extra onus to ensure that decisions are as 'correct' as possible. Relatedly, because of this point, it is the case that many researchers still find appealing cognitive modeling on the basis of CP principles (e.g., Oaksford & Chater, 2009), despite the evidence that, in many practical situations, modeling approaches based on e.g., heuristics and biases may have a higher descriptive value (Gigerenzer & Todd, 1999; Gigerenzer, 1991; Kahneman & Tversky, 1996; Kahneman et al., 1982).

It is these points which motivate the approach in the present article, based on quantum probability (QP) theory. QP theory is a formal framework for how to assign probabilities to events, and so it is possible to develop some normative arguments for QP theory, analogous to those for CP theory (Pothos & Busemeyer, 2014). Equally, some processes in QP theory appear to have natural interpretations in terms of existing, well-known heuristics, such as the representativeness or availability heuristics (cf. Busemeyer & Bruza, 2012; Pothos & Busemeyer, 2013). It is then possible that QP theory can provide a perspective on organizational decision making, which is close to descriptive assumptions from relevant heuristics and biases and, equally, consistent with the general, a priori arguments, which motivate CP accounts and corresponding normative considerations. Our specific objective is to provide some preliminary discussion of whether such an exciting (though, also, ambitious) objective might be achievable or not.

Many of the decision making phenomena that have been studied as part of the QP research program concern situations for which the normative (from CP theory) prescription goes against a very strong intuition for an alternative decision. Intuition has been defined as "affectively-charged judgments that arise through rapid, non-conscious, and holistic associations" (Dane & Pratt, 2007: 40). Intuition is seen as important in the use of heuristics (e.g., Kahneman & Tversky, 1982; Klein, 1998, 2003), produces decisions that can at times appear irrational, at least without detailed analysis (e.g., Klein, 1998), and as a process is itself difficult to explain rationally (Dane & Pratt, 2007). Both CP theory and QP theory are, in part, intended as theories for how intuitions regarding the relative likelihood of different possibilities develop. While the work just cited indicates a divergence between predictions from CP models and current understanding about intuition, a consideration of QP theory can lead to alternative conclusions.

QP theory was devised to explain paradoxical findings in quantum physics that could not be understood using classical theories. It is based on axioms fundamentally different from those of CP theory and so corresponding probabilistic inference involves characteristics (such as superposition, incompatibility, and entanglement), with no analogs in classical theory. It has helped physicists understand, for example, how different events within a system interfere with one another and how the measurement of a system influences the state of the system. Such phenomena are also observed in decision making research, for example, in relation to order effects (e.g., Hogarth & Einhorn, 1992) and the constructive role that making a choice can have on underlying preferences (e.g., Payne, Bettman, & Johnson, 1993; Sharot, Velasquez, & Dolan, 2010). So, proponents of the application of QP theory in cognition have argued that these special characteristics of QP align well with human decision making under uncertainty, at least under some circumstances. In fact, human decision making behavior, which may appear paradoxical or irrational from a classical perspective, often has a simple and natural explanation in terms of QP principles. Of relevance is also the fact that, in QP theory, the incompatibility of certain possibilities means that their probabilistic computation needs to be sequential, so that, for example, even conjunctions need to be assessed in a sequential way. Such requirements make QP theory computation closer to process assumptions and so, perhaps, more suitable for modeling the situations of applied decision making that we are interested in. In general, it has been suggested that incorporating process assumptions into cognitive models is an appropriate direction for their development (Jones & Love, 2011; cf. Newell, 1990).

The structure of our contribution in this Special Issue is as follows: first, we will briefly summarize QP theory and consider the motivation for exploring its application in cognitive modeling. It is not our intention to provide a comprehensive overview of QP theory research, for reviews see, for example, Busemeyer and Bruza (2012), Khrennikov (2010), Pothos and Busemeyer (2013) and Wang, Busemeyer, Atmanspacher, and Pothos (2013). Second, we will consider some of the key insights about human decision making, from existing QP cognitive models, as developed in the context of particular empirical applications (mostly based on Busemeyer & Bruza, 2012; Pothos & Busemeyer, 2009; Trueblood & Busemeyer, 2011; Wang & Busemeyer, 2013). The selection of empirical applications will be motivated from corresponding conclusions that human behavior deviates from the prescription of CP theory. Of course, there are often typically powerful non-CP theory accounts for such findings (e.g., Gigerenzer & Selten, 2001; Marewski & Schooler, 2011; Tversky & Kahneman, 1983). The emphasis on CP theory relates to the emphasis on normative considerations in this paper. As discussed, we think that this is a valuable approach, especially in situations of applied significance, where decision makers may be particularly keen to achieve decisions considered 'correct' in some formal sense (since deviations from normative prescription may lead to e.g., material loss). For each of these insights/applications, we discuss the new perspective that QP provides on organizational decision making and the possible implications and benefits. That is, our discussion will be more focused on the normative perspective (conflicts with CP theory and corresponding QP theory insights), less so by the descriptive or bounded rationality perspective, provided by models based on heuristics and biases (though, obviously, both perspectives are valuable).

Inevitably, some of the recommendations in this paper, in relation to QP theory, will involve speculation. Our work so far has focused on establishing the formal validity of QP cognitive models, against empirical results of high prominence in the decision making literature. There has been little systematic investigation or empirical research into the applicability of QP models in organizational settings (for exceptions see the work of Lawless and his colleagues discussing how principles of QP can be applied to modeling social dynamics, such as cooperation and competition, in teams and organizations; Lawless & Sofge, 2012; Lawless & Grayson, 2003; Lawless, Bergman, Louçã, Kriegel, & Feltovich, 2007; Lawless et al., 2011; see also Yukalov & Sornette, 2012, who apply their quantum decision theory (Yukalov & Sornette, 2008), a theory developed for individual personal decision making, to decision makers under the influence of other social agents). We hope that this paper can serve to inspire further work toward an applied direction for the QP cognition program, in relation to organizational decision making. The ideas we outline below provide an alternative perspective for rationality and optimality in probabilistic inference and motivate a discussion of implications (and possible aids) in organizational decision making.

2. An outline of quantum probability theory

QP theory is a theory for how to assign probabilities to events. It is best known in its application to physics, in the context of quantum mechanics. But, the rules regarding probabilistic assignment