Cultural Quantum Cognition and Decision

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Abstract—Recent advances in cultural psychology elucidated a number of cultural differences in diverse psychological characteristics and behaviors from perceptions, and economic decisions to religiosity. Also, quantum models of cognition and decision making have been developed to mathematically characterize perceptions, and human judgement and decision making. This study proposes cultural quantum modelling approaches to cultural psychology and neuroscience, by utilizing the mathematical model of quantum cognition and decisions in psychology, economics, and decision science. This approach may help better quantitatively rigorous understandings of cultural differences between Westerners and Easterners, Catholics and Protestants, and other cross-cultural variations in psychological and behavioral characteristics and normative principles of rationality.

Keywords: culture, quantum theory, cognition, decision, rationality

Introduction

Recent advances in quantum cognition and decision theory have witnessed useful applications of quantum probability theoretical models in the studies of human perception (Atmanspacher et al., 2004), judgement (Franco, 2007), cognition and decision making (see Khrennikov,2010;　Busemeyer and Bruza, 2012; Yukalov, & Sornette、2010; Cheon & Takahashi, 2010). However, cultural differences in human psychology have been largely underexplored. Studies in cultural psychology revealed a number of cultural differences and similarities in perception (Nisbett & Miyamoto, 2005), judgment (Norenzayan, Choi, & Nisbett, 2002), cognition (Nisbett, Peng, Choi, & Norenzayan, 2001), and decision making (Weber & Hsee, 1998)., indicating the potential importance of how these differences and similarities are quantified by utilizing the quantum theoretical models.

Savage's sure-thing principle and Nozick's dominance principle

The Sure-Thing Principle (STP) famously appears in Savage's axiomatization of Subjective Expected Utility (SEU; Savage, 1954, 1972). In the section of which title is "The Sure-Thing Principle", Savage introduces the principle of rationality as follows (1954, p. 21) :

> "A businessman contemplates buying a certain piece of property. He considers the outcome of the next presidential election relevant to the attractiveness of the purchase. So, to clarify the matter to himself, he asks whether he would buy if he knew that the Democratic candidate were going to win, and decides that he would. Similarly, he considers whether he would buy if he knew that the Republican candidate were going to win, and again finds that he would do so. Seeing that he would buy in either event, he decides that he should buy, even though he does not know which event obtains …[E]xcept possibly for the assumption of simple ordering, I know of no other …principle governing decisions that finds such ready acceptance."

In this way, Savage illustrated the principle in terms of states of decision-maker's knowledge. On the other hand, in literature of behavioral economics on "disjunction effect" in choice under uncertainty (Tversky & Shafir, 1992), this principle has been introduced as:

> "One of the basic axioms of the rational theory of decision under uncertainty is Savage's (1954) sure-thing principle (STP) It states that if prospect x is preferred to y knowing that Event A occurred, and if x is preferred to y knowing that A did not occur, then x should be preferred to y even when it is not known whether A occurred."

This principle of rationality has conventionally regarded as a principle of dominance. (Savage, 1954; Jeffrey, 1983). Robert Nozick (1969), in his famous analysis of the paradox in the Newcomb's decision problem, defined the dominance principle as follows:

> "Dominance Principle: If there is a partition of states of the world such that relative to it, action A weakly dominates action B, then A should be performed rather than B.
> Action A weakly dominates action B for person P iff, for each state of the world, P either prefers the consequence of A to the consequence of B, or is indifferent between the two consequences, and for some state of the world, P prefers the consequence of A to the consequence of B."

It is to be noted that in these types of formulation, there are no probabilistic concepts. However, when testing the Savage's sure-thing principle, participant's choices between two alternative A and B is not strictly always the same; that is, Participants do not invariably choose option A; nonetheless, they tend to choose A more frequently (or likely) than B. Hence, it is useful to state this principle in a probabilistic manner.

Relation between Savage's sure-thing principle and the law of total probability

Several authors framed Savage's sure-thing principle probabilistically (Jeffrey, 1982; Khrennikov, 2010; Cheon and Takahashi, 2010). Most frequently utilized formulation in behavioral and psychological studies testing the violation of this principle is the formulation as a special case for the fundamental characteristics of probabilities: the law of total probability. The law of total probability is, in the simplest case of dichotomous random variables, a = ± and b = ±:

$$P(b = \pm) = P(a=+)P(b = \pm|a=+) + P(a=-)P(b=\pm|a=-) \quad (1)$$

Thus the probability P(b = ±) can be decomposed into conditional probabilities P(b = ±|a = ±). This formula always holds in Kolmogorovian probability theory.

Here we put "prospect x is preferred to y" as "b=+" and "knowing Event A occurred" as "a=+" and "knowing that A did not occur" as "a=-", in Tversky and Shafir (1992)'s formulation of Savage's sure-thing principle, P(b =+|a=+)= P(b =+|a=-)=1. Then, from the law of total probability (equation 1), we obtain the decomposition of P(b = +) in terms of the conditional probabilities:

P(b = +) =P(a=+)P(b =+|a=+)+P(a=−)P(b=+|a=−) = P(a=+)+P(a=−)=1.

This indicates that the unconditional probability (the probability when the condition is unknown) of "prospect x is preferred to y" P(b = +) is 1, corresponding to "x should be preferred to y even when it is not known whether A occurred" in Tversky and Shafir(1992)'s formulation. Therefore , Savage's sure-thing principle is the special case of the law of total probability when P(b =+|a=+)= P(b =+|a=-)=1. A number of studies in quantum cognition and decision models (Shafir and Tversky, 1992; Tversky and Shafir, 1992; Khrennikov, 2010) have utilized equation 1, rather than Savage's original formulation, for testing whether human decision-making violates this principle.

When the violation of Savage's sure-thing principle was first tested by behavioral economists Tversky and Shafir (Shafir and Tversky, 1992; Tversky and Shafir, 1992), in decision problems the Prisoner's Dilemma, Newcomb's problem, Wason's four card problem and Hawaii problem, the law of total probability was tested in the following manner: they experimentally measured values of the two conditional probabilities P(b =+|a=+) and P(b=+|a=−), and additionally the value of the unconditional probability P(b = +). Then they checked whether the value of P(b = +) is in between P(b =+|a=+) and P(b=+|a=−). Because P(a=+)+P(a=−)=1, if the law of total probability holds, the value of P(b = +) should be in the range between the values of P(b =+|a=+) and P(b=+|a=−). Consequently, they observed, in most experimental tasks, that the participants' value of P(b = +) was outside of the range between the values of P(b =+|a=+) and P(b=+|a=−), concluding that Savage's sure-thing principle was violated.

Quantum models of cognition and decision for the violation of Savage's sure-thing principle

Subsequent studies in quantum cognition and decision models (see Khrennikov 2010, for introductory explanations) utilized the formula of probabilities in quantum

theory, in which so-called "interference term" I appears, as is the usual case in quantum theory in physics, in the right-hand side of equation 1:

$$P(b = \pm) = P(a=+)P(b = \pm|a=+) + P(a=-)P(b=\pm|a=-) + I \qquad (2)$$

which can capture the violation of Savage's sure-thing principle in a quantitative manner. Originally, for modelling probability judgement errors in humans, Franco quantified, by utilizing quantum settings, the interference term as

$$I = 2\sqrt{P(a = -)P(a = +)P(b = \pm|a = +)P(b = \pm|a = -)}\cos\theta, \quad (3)$$

where θ is a parameter called quantum phase in quantum theory. This expression has been widely utilized to model the violation of Savage's sure-thing principle and other human probability judgement errors, and extended to a two-quantum phase model in the later study (Cheon and Takahashi, 2010).

Cultural differences in judgement and decision-making

In the fields of cultural psychology, neuroscience, and neuroeconomics, a number of studies have revealed cultural differences and similarities in judgement and decision-making (Nisbett & Miyamoto, 2005; Weber & Hsee, 1998). Cultural differences in cognition have been widely documented (Markus & Kitayama, 1991; Nisbett, Miyamoto, & Kitayama, 2005; Kitayama & Uskul, 2011). We have also reported cultural differences in temporal discounting (Takahashi et al., 2009).

In a seminal paper on the violations of the Savage's sure-thing principle in decision making through uncertainty, Shafir and Tversky (1992) stated that:

> "Quasi-magical thinking, we believe, underlies several phenomena related to self-deception and the illusion of control. Quattrone and Tversky (1984), for example, noted that Calvinists act as if their behavior will determine whether they will go to heaven or to hell, despite their belief in divine predetermination, which entails that their fate has been determined prior to their birth. "

And furthermore,

> "Calvinists would perhaps do fewer good deeds if they knew that they had already been assigned to heaven, or to hell, than while their fate remains a mystery."

Shafir and Tversky (1992) attributed to this violations of Savage's principle to nonconsequential reasoning, that is, when thinking under uncertainty, people often do not consider appropriately each of the relevant branches of a decision tree, as required by consequentialism. Here, it is noteworthy that Nobel prize-winning economist Gary Becker (1968) proposed an economic theory of criminal behavior in which the illegal behavior is motivated by rational, reward-maximizing incentives. This theory assumes criminals are rational in that they follow the expected utility theory which is compatible with Savage's sure-thing principle. Becker's rationality is based on consequentialism and utilitarianism. Therefore, contrary to Shafir and Tversky's hypothetical Calvinists, Becker's criminals do not refrain from illegal acts if the acts are lucrative, even when the criminals do not know whether they are assigned to heaven or to hell and their fate remains a mystery. By analyzing real world evidence of crime rates, Adamczyk and colleagues (2017) reported that religion tends to have a deterring influence on crime-related attitudes and behaviors. Unfortunately, in Adamczyk et al.'s study, it is not distinguish the religion is Calvinism or not (e.g., Catholicism). Therefore, future studies should examine how cultural differences in the violations of the sure-thing principle with the utilization of the quantum probabilistic models, between Calvinists and Catholics determine differences in crime rates between these religions. Moreover, with the few exceptions of Li et al (2010) and Ishibashi-Ohmura and Takahashi (2015)' studies conducted in China and Japan, most experimental studies of the violations of Savage's sure-thing principle have been conducted in Westerners. Cultural psychologist (Markus and Kitayama, 1991) state that Westerners and Easterners differ in their cognition and decision. We also reported that intertemporal choice patterns differ between North Americans and Japanese. Hence, quantum modelling studies should examine whether quantum phases (and the size of the interference effect, equation 3) in the models differ between Westerners and Easterners.

Cultural differences in quantum probabilistic quasi-magical thinking

Shafir & Tversky introduce the notion of quasi-magical thinking to describe decision-behaviors in which people behave as though their own action can influence an outcome, even when they explicitly know (or claim to know) no causal link exists. For example, in a one-shot version of the Prisoner's Dilemma Game, Shafir and Tversky

experimentally demonstrated that participants are likely to cooperate when they do not know what the other person (opponent) has done, whereas they defect (compete) when they know the other has either defected or cooperated—behavior that violates standard principle of consequential rationality. Shafir & Tversky describe this as people acting as if "my cooperating influences the other's choice" (even though logically it does not). Behavioral economic data of cooperation (i.e., quasi-magical thinking tendency) in the Prisoner's Dilemma Game have been modeled with quantum probability theories. Therefore, cultural differences in quasi-magical thinking in social cooperative behaviors should be modeled with the quantum interference effects (equation 3).

Interestingly, Shafir and Tversky (1992)'s study introduced the following quantum physicist Niels Bohr's anecdote to demonstrate that the violation of Savage's sure-thing principle corresponds "quasi-magical thinking":

> "It is told of Niels Bohr that, when asked by a journalist about a horseshoe (purported to bring good luck) hanging over his door, he explained that he of course does not believe in such nonsense, but heard that it helped even if one did not believe."

Niels Bohr, a father of quantum physics and Copenhagen interpretation of quantum theory, wrote about relationships between natural philosophy and human culture (Bohr, 1958). This indicates that Bohr legitimately recognized the importance of human culture in forming the interpretations of quantum theory. Future studies thus should examine the relationship between culture and various interpretations of quantum theory.

Conclusions

Cultural differences and similarities in judgment and decision making, particularly under uncertainty, should be quantified and examined with quantum probabilistic models. This may help a better understanding of social norms in different cultures in a quantitative manner.

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