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How do the social norms and expectations about others influence individual behavior?

Quantum model of self/other-perspective interaction in the strategic decision-making

Abstract: *A social norm can be understood as a kind of grammar of social interaction (Bicchieri 2006). As grammar in the speech, it specifies what is acceptable in the given context. But what are the specific rules of the 'grammar of social interaction'? This paper presents a quantitative model of the self- and the other-perspective interaction based on so called 'quantum model of decision-making', which can explain some of the 'fallacies' of the classical model of traditional choice. The model enables to define how the actor`s expectation about others influence his decision (and vice versa). The model was designed for the strategic interaction of two players and tested in the case of one-shot Prisoner's Dilemma game. The results confirm the prediction of the model, including quantitative prediction in the form of the q-test. Quantum model of decision-making offers a new conceptual framework for examining the interaction of the self- and the other-perspective in the process of social interaction. It enables to specify how the social norms influence individual behavior in the way that is consistent with the known qualitative and quantitative results.*

Key words: *social norms, quantum model of decision-making, agent-structure problem*

Introduction

The topic of this work is the nature of social norms and the way in which they influence the reasoning and behavior of the individual actor, and more specifically, the compliance with the norm. In the literature, this problem is mainly considered from the perspective of one of the three broad approaches: using the theory of a socialized actor, the concept of group norms or the theory of rational choice (Bicchieri and Muldoon 2014). Our approach is closely related to the theory of rational choice as it uses game theory as the formal model of this interaction. Nevertheless (as we will see by the end of this paper), our conclusions are to the great extent close to the Parsons approach of internalized norms that somehow shape not only the behavior of the actor but also his self-concept.

What is it known about the mutual relationship of the social norms and the human behavior? From current literature, we know, that the existence of the norm itself does not lead to its compliance. The expectations about the others play a key role. Specifically Bicchieri and Xiao argued that *"two different expectations influence our choice to obey a norm: what we expect others to do (empirical expectations) and what we believe others think we ought to do (normative expectations)"* (Bicchieri and Xiao 2009, 191). In other words, actors follow the norm only if they a) assume the others will follow the norm as well; and they b) assume that also the others expect the compliance with the norm from them. We add also one intuitive assumptions that precede the above, which is that actors know the norm, and are reasoning about it in their decision-making. These findings form a basic qualitative characteristic of the actor/social norm interaction. How can we formalized them to get a concrete description and possibly also the quantitative predictions?

The prominent approach models this problem by the Bayesian theory of rational choice. It uses the formalism of the game theory and define the social norm mainly as the Nash equilibrium of the respective game (Schelling 1960; Lewis 1969; Ullmann-Margalit 1977; Sugden 1986; Elster 1989; Binmore 2005). More recently, Bicchieri (2006) argues that the mixed-motives games do not offer the equilibrium solution. Instead, the existence of the norm transforms the game into the coordination game, which creates the equilibrium as e.g. the mutual cooperation in Prisoners' Dilemma game. The game-theoretic argument has been pushed further by Gintis (2014), who argues that social norm is the choreographer of the particular epistemic game.

Even though the game-theoretic approach is the most prominent approach by now, it is not without problems. Probably the most important among them is the existence of several phenomena that seems to contradict the basic axioms of Bayesian rationality which in turn create the common ground for all the rational choice approaches. The phenomena like the *order effect* (Moore 2002) or the *conjunction effect* and the *disjunction effect* (Tversky and Shafir 1992; Croson 1999) that are present in the laboratory experiments shows that the assumptions of Bayesian rationality are often violated. The authors, when reflecting this problem, refers often to the Kahnemann's heuristics (e.g. Gintis 2014, para. 1.5.4) while assuming this is only a small departure from the 'fully' rational behavior (i.e. bounded rationality), leaving the question of validity of rational choice assumptions unanswered. The vast majority of the literature (with some exceptions, e.g. Shu Li et al. 2010) neglects that these effects can stem from a more fundamental problem with our notion of rationality. For example, the disjunction effect which violated the Savage's *sure thing principle* (Savage 1972) and which has not been sufficiently explained by the classical model, clearly contradicts one of the Gintis' axioms that is used to build the main algebraic structure of his book (Gintis 2014, 15–16).

If there are well-founded doubts about the validity of our rationality assumption, what can be done? Is there any algebraic structure that can model strategic interaction of the players, and explain known effects of 'bounded rationality'? The alternative approach, so called *quantum models of decision-making*, developing in the last 10 years mainly in cognitive psychology (see Busemeyer and Bruza 2014 for a review), can offer this option. These models use the mathematical structure of the quantum probability theory and models a given situation as the vector in N-dimensional vector space (von Neumann's C*-algebra) instead of the classical probability theory that use the set theory (Kolmogorov's sigma-algebra). Our main research question in this paper is whether these models, which has been successfully used for the explanation of the 'cognitive fallacies', can account also for the rules of 'social grammar', i.e. whether they can explain the known features of the social norms compliance.

The paper proceeds as follows. In the next chapter I will introduce the quantum model of strategic decision-making. First, in the general form and second, in the form of the 'toy model' which enables me to illustrate its advantages in the restricted space of this paper. I will compare the model to the classical one and derive the key prediction for the case of strategic interaction of the two players. In the next chapter I will present the results of an experiment, that was designed to test our toy model. The results show that all the main prediction of the model was met and that the model can account for all the known effects. Then I will discuss some consequences of the quantum model for future exploring.

Quantum model of the interaction of the perspectives

Our goal in this chapter is to introduce the quantum model of strategic decision-making and use it to make some prediction about the behavior of the actor in relationship to the expectations that he has about the other players. To make the model more intuitive we will constrain to the simplest situation where the actor chooses between two alternatives which are symmetric for both players. We will describe the situation in the classical and the quantum model to show the key difference between them.

Let's assume, that the player face a situation, where the choices available to him are the strategies from the strategic set $S \in \{A, B\}$ and the he chooses strategy A with probability t and strategy B with probability $(1-t)$. This is the choice in the self-perspective. Regarding the other player, we denote the expected strategy of the other player $S' \in \{A', B'\}$ and we assume the player expects strategy A' with probability t' and B' with probability $(1-t')$. This is the choice in the other-perspective.

Classical model of strategic decision-making

Traditional choice theory models this situation with help of the set theory and can be illustrated by the **Error! Reference source not found.**.

Table 1

A *and* A'	A *and* B'
B *and* A'	B *and* B'

We assume, that every player belongs to one of the four quadrants in Table 1. In other words, he is characterized by one of the following options: i) he prefers A while assuming B'; ii) he prefers A while assuming A'; iii) he prefers B while assuming A'; iv) he prefers B while assuming B'. But what exactly means that he e.g. prefers A while assuming B'? Here we have two of his different features, which can be determined in the different settings. We either can determine his choice of the strategy and then his expectation (AB') or his expectation and then his strategy $(B'A)$. Is there any difference between these two settings? There isn't from the point of view of the classical theory, for the operation of the set disjunction (logical and) and the set conjunction (logical or) are commutative, i.e. the sets $\{A\ and\ B'\}$ are $\{B'and\ A\}$ are identical. The probability to pick a player from the set (A and then B') or (B' and then A) must also equal: $p(AB') = p(B'A)$. Of course, this logic is valid for all the quadrants, and is not disrupted even by the probabilistic nature of choice (mixed strategies and probabilistic priors). We can see that the commutativity of the set operations is the direct reason, why the classical concept of probability cannot account for the order effect.

There are other consequences of the commutativity of set operations. The overall probability of the choice A can be expressed also as the sum of the sequential probabilities $p(A) = p(AA') + p(AB')$. (It is the sum of the probability that a player chooses A and then expects A' and the probability that he chooses A and then expects B'). But if we know, that the sequential probability is order independent, we can rewrite it as:

$$p(A) = p(AA') + p(AB') = p(A'A) + p(B'A)$$

By defining $p(A'A) = p(A') \cdot p(A|A')$ and $p(B'A) = p(B') \cdot p(A|B')$, where $p(A|A')$ is the probability of A conditioned on previous choice A', and $p(A|B')$ is the probability of A conditioned on previous choice B' it is:

$$p(A) = p(A') \cdot p(A|A') + p(B') \cdot p(A|B')$$

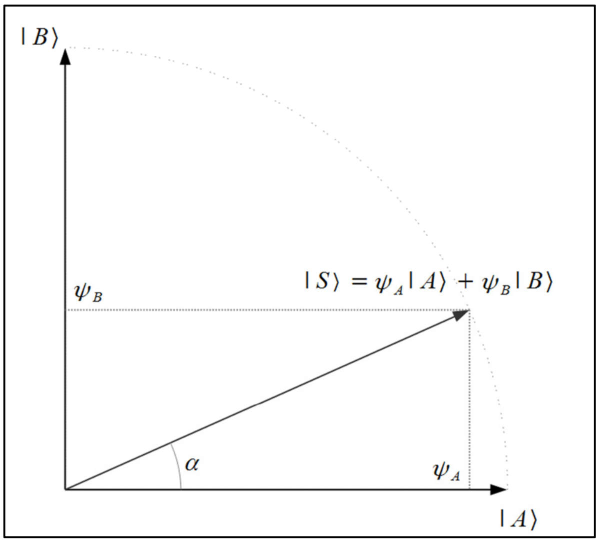
This already is the *law of total probability* (a weaker form of the Sure thing principle), which is violated in the Disjunction effect (Tversky and Shafir 1992).

Quantum model of strategic decision-making (toy model)

Alternatively, the quantum model of strategic decision-making, represents the initial state of the player not as member of some set with well-defined preferences and expectations (even though probabilistic), but as a vector in the complex vector space[i]. Specifically, it is a unit-length vector called state vector in the Hilbert space over the field of complex numbers (for introduction see Busemeyer and Bruza 2014, chap. 2). The bases of this vector space are the vector that belong to the strategies from the strategic set. Model defines the probability of individual strategies as the square root of the orthogonal projection of the state vector into the respective basis vector. The full description of the quantum model is far beyond the space here, but the general model, including necessary mathematical formalism, can be found in the *Quantum models of cognition and decision* (Busemeyer and Bruza 2014) and the case of strategic interaction of two players in my previous work (Tesař forthcoming). Here, I restricted myself to the 'toy model', which can explain the main features of the decision-making process and can be illustrated with the use of common mathematical concepts.

So, how does the strategic choice look like in the quantum model? The vector space which we will use to describe the situation, is the 2-dimmensional vector space over the field of real numbers (this is the key aspect where the toy model deviates from the fully-equipped one) with two mutually orthogonal vectors $|A\rangle$ a $|B\rangle$[ii] that belongs to the strategies A and B from the self-perspective strategic set $S \in \{A, B\}$. Then the initial state vector of the player $|S\rangle$ is a unit-length vector starting from the origin of the coordinates and ending on the circle with radius 1, as is shown in Figure 1. The position of the vector $|S\rangle$ in relationship to vectors $|A\rangle$ and $|B\rangle$ is specified by the coefficients of the linear combination ψ_A and ψ_B, or equally by the angle α which is the angle between the state vector and basis vector $|A\rangle$. The mutual relationship of the coefficients and angel α is given by: $\cos\alpha = \psi_A$, $\sin\alpha = \psi_B$ and $\psi_A^2 + \psi_B^2 = 1$.

Figure 1



Next step of the model is the assumption, that the probability of some choice is given as a square root of the orthogonal projection of the state vector into the respective basis vector. Therefore, in our toy model $p(A) = (\cos\alpha)^2$ a $p(B) = (\sin\alpha)^2$.

How does the model include the player's expectation about the others? The pair of basis vectors which defines the other-perspective is $|A'\rangle$ and $|B'\rangle$ and, for the sake of generality, the basis is rotated from the self-perspective by a general angle β as is apparent in Figure 2.

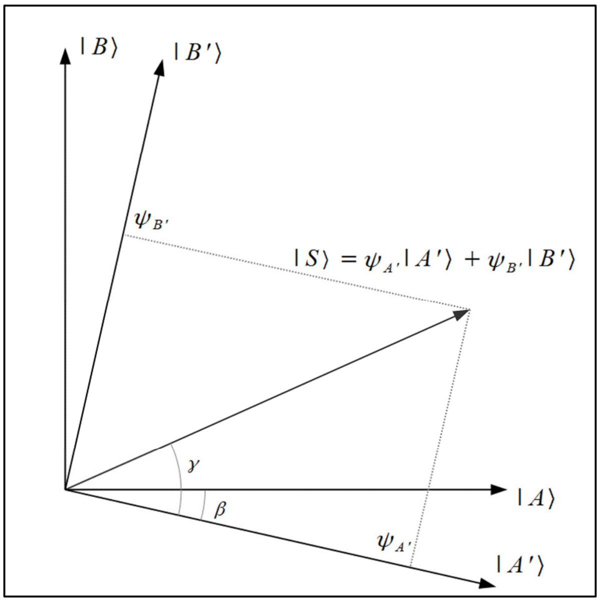


Figure 2

The state vector is in the other-perspective given by a pair of coefficients of the linear combination $\psi_{A'}$ a $\psi_{B'}$, or equally by the angle γ, which is the angle between the state vector and basis vector $|A'\rangle$. The mutual relationship of the coefficients and angel γ is given by: $\cos\gamma = \psi_{A'}$, $\sin\gamma = \psi_{B'}$ and $\psi_{A'}^2 + \psi_{B'}^2 = 1$. The probability that the player expects A' is $p(A') = (\cos\gamma)^2$, and similarly $p(B') = (\sin\gamma)^2$.

The last aspect of the model which needs to by specified is the change of the state vector after the first choice. If the player makes the choice, his state vector is 'projected' into the respective basis vector and this vector (normalized to be of a unit-length) becomes his new state vector. If for example the player is choosing his own strategy, then with the probability $p(A) = (\cos\alpha)^2$ he chooses strategy A, and *immediately after that* his state vector becomes the basis vector

$|A\rangle$ s with probability 1. Then, if the player chooses in the other-perspective, the probability of his choice is defined by the projection of his new state vector $|A\rangle$ into $|A'\rangle$, respective $|B'\rangle$ and is given by the angle β. Namely, the probability to choose A' after A is $p(A'|A) = (\cos\beta)^2$, similarly $p(B'|A) = (\sin\beta)^2$. The overall probability of the sequence (AA'), which is depicted in Figure 3, is therefore given as $p(AA') = p(A) \cdot p(A'|A) = (\cos\alpha)^2 \cdot (\cos\beta)^2$.

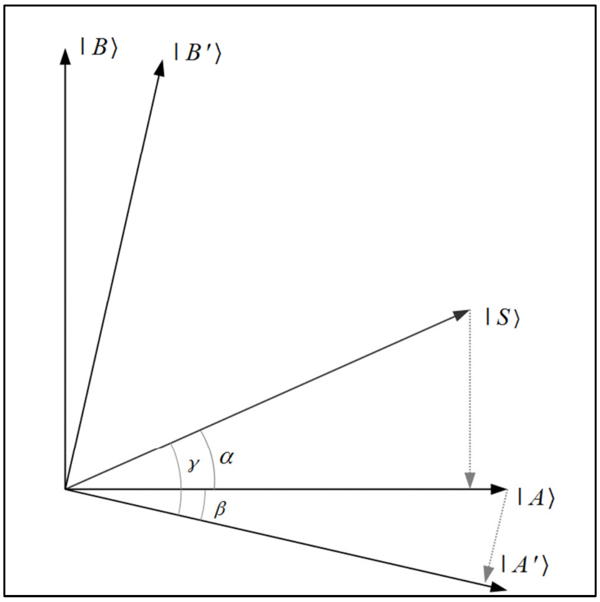


Figure 3

How does this model explain the order effect and the disjunction effect? First, we notice that the logic introduced here is not commutative. The projection of the state vector in the self-perspective is given by the angle α, while in the other-perspective by the angle γ. Second, the subsequent transition between the two perspectives is symmetric, i.e. the probability of it is the same in both directions ($p(A'|A) = p(A|A')$). Putting together, we see that if the two perspectives differ ($\beta \neq 0$), then the order effect exists. Specifically, we saw that $p(AA') = (\cos\alpha)^2 \cdot (\cos\beta)^2$ whereas the reverse order gives $p(A'A) = (\cos\gamma)^2 \cdot (\cos\beta)^2$ and the two probabilities differ.

From the order effect stems also the possibility of the violation of the law of total probability. If the opposite ordering of the questions does not lead to the same probability, we get

$$p(A) = p(AA') + p(AB') \neq \; p(A'A) + p(B'A)$$

and that explain the possible presence of the disjunction effect. Instead of the previous equation we get

$$p(A) = p(AA') + p(AB') = \; p(A'A) + p(B'A) + Int.A$$

where $Int.A$ is the *interference term*, which due to the influence of the other-perspective increase (for $Int.A < 0$) or decrease (for $Int.A > 0$) the probability of choice A if the other-perspective is considered first.

From the above presented features of the quantum model it is evident that this model does not allow the two perspective to be decided (or known) in the same time. We know the answer in the self-perspective or in the other-perspective, never both at the same time. This is the form of the well-known *uncertainty principle* which says that if the two variables are *non-compatible* (which is equivalent to say that their bases differ), we cannot determine the exact value of both with a single ‘measurement’. The question “what is the player’s strategy and simultaneously his expectation about others” is irrelevant in the quantum model. All we can know regarding both the perspectives, is the sequential probability in two different forms of self-perspective first or other-perspective first.

Self/other-perspective interaction in the quantum model

In the previous section, we defined the toy quantum model of strategic interaction. In this section, we turn to the main question of this paper which is whether this algebraic structure can account for the known features of the actor/norm interaction where the key role play his expectation about the anonymous others. To answer this question, we are going to continue in the presented model (2-dimmensional over the field of real numbers), but for the higher intelligibility we will turn to the concrete example of the strategic interaction of two players in the one-shot Prisoners' Dilemma game and the hypothetical norms of cooperation and selfishness.

Consider the situation in the Figure 4. The basis vectors in the self-perspective are $|C\rangle$ and $|D\rangle$ and belongs to the strategies of cooperation and defection. In the other-perspective they are $|C'\rangle$ and $|D'\rangle$ and belongs to the expected cooperation respective defection of the anonymous other. The initial state vector is in the self-perspective given by α, in the other-perspective by γ, and the mutual relationship of perspectives by β.

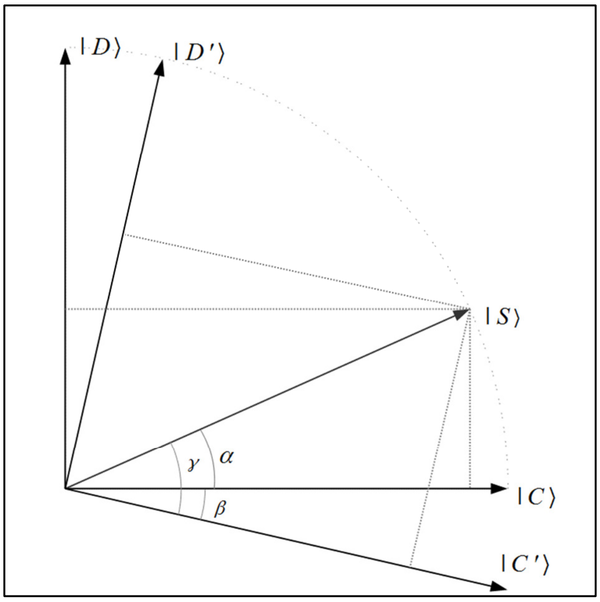


Figure 4

To determine how the expectation about the others can influence player's behavior, we are going to analyze the mutual relationship of three variables: i) player's level of cooperation, ii) player's expectation about the level of cooperation by others, and ii) the relation of the perspectives. Without loss of generality[iii] we can assume $\alpha \in (0, 45°)$ and keep it constant while manipulating β and γ. The influence of the other-perspective will be analyzed in the first step in the interval $\beta \in (\alpha - 90°, \alpha)$, where the bottom limit corresponds to the situation that player expects all others to defect and the upper limit to his expectation of the full cooperation of the others.

We will start with the analysis of the situation in Figure 4, where $\beta \in (\alpha - 90°,\ 0°)$ and $\gamma \in (0°, 90°)$[iv]. The player tends to be cooperative, his level of cooperation is $p(C) = (\cos\alpha)^2$. And what are his expectations? Does he expect higher or lower level of cooperation from the others? The probability of expected cooperation is $p(C') = (\cos\gamma)^2$. As the cosine is the monotonously declining function in the given interval and $\alpha < \gamma$, it follows that $(\cos\alpha)^2 > (\cos\gamma)^2$. I.e. that $p(C) > p(C')$ and the player expects lower cooperation of the others than he is willing to play. How does this expectation influence his choice if he considers the other-perspective first? It is not hard to show, that in this case $p(C) > p(C'C) + p(D'C)$, i.e. *the decision in the other-perspective beforehand his choice in the self-perspective decrease his willingness to cooperate*. To sum it, in the interval $\beta \in (\alpha - 90°, 0°)$ the player expects less cooperation from others and, if he takes the other-perspective into account, it leads to the lower level of his cooperation (in comparison to the 'direct' decision in his self-perspective). This situation therefore corresponds to the influence of the *selfish norm*.

We can apply the same procedure for $\beta \in (0°, \alpha)$ and $\gamma \in (\alpha, 0°)$. Here $\alpha > \gamma$ therefore $(\cos\alpha)^2 < (\cos\gamma)^2$ and the player expects higher level of cooperation from the others. The overall effect of reasoning about the others is positive, $p(C) < p(C'C) + p(D'C)$. To sum it, for $\beta \in (0°, \alpha)$ the player expects more of cooperation from the others which leads, if he takes it into account, to his higher level of cooperation. There is a *cooperative norm* at play in this interval.

We can extend the analysis also to the interval $\beta \in (\alpha, \alpha + 90°)$, but here the player expects the 'reverse' view from others (his $|C\rangle$ is located on the opposite side of the state vector than his $|C'\rangle$) which can lead to at-the-first-sight paradox conclusions. In the interval $\beta \in (\alpha, 2\alpha)$ the player expects more cooperation from the others, but taking it into account it leads to the lower level of his cooperation. For $\beta \in (2\alpha, 90°)$ there is the selfish norm at play, and finally for $\beta \in (90°, 90° + \alpha)$ the player expects less cooperation from the others, but taking it into account it leads to his higher level of cooperation. We can sum our findings in the following table.

Table 2

Interval for beta and gamma[v]	The others are expected to be more …	The decision in the other-perspective increases player`s probability to …	Type of the self/other-perspective interaction
$\beta \in (\alpha - 90°, 0°)$ $\gamma \in (90°, \alpha)$	selfish	defect	Compliance with the selfish norm
$\beta \in (0°, \alpha)$ $\gamma \in (\alpha, 0°)$	cooperative	cooperate	Compliance with the cooperative norm
$\beta \in (\alpha, 2\alpha)$ $\gamma \in (0°, -\alpha)$	cooperative	defect	Defiant defection
$\beta \in (2\alpha, 90°)$ $\gamma \in (-\alpha, \alpha - 90°)$	selfish	defect	Compliance with the selfish norm
$\beta \in (90°, 90° + \alpha)$ $\gamma \in (\alpha - 90°, 90°)$	selfish	cooperate	Defiant cooperation

From the analysis above stems also the interpretation of the angles in our toy model. The angle α determined player's willingness to cooperate. The angle γ accounts for his expectation about the cooperation of the others, so it corresponds to his *empirical expectations*. The key role plays the angle β, which corresponds to his *normative expectations*. Small betas (close to 0°, first two rows of the Table 2) correspond to the 'closeness' of both perspectives and the reasoning about the other-perspective strengthen the strategy that the player expect the others play more often than he. In contract, large betas correspond to the disparity between the perspectives, to the 'protest view', where the reasoning about the others strengthen the strategy that the player expect to be played less often then he would play it (cooperation or defection 'in spite' of the others). The mutual relationship of these three angles determines whether there is the norm of cooperation or the norm of selfishness or if these strategies go against each other.

The limitation of the toy model

Before we proceed to the summation of the prediction of the quantum model, we should discuss the limitations of our toy model. What is the nature of the toy model? How does it differ from the fully-equipped quantum model? The deviations are of two kinds. First, we can model the strategic interaction of two players in vector space of different dimensionality. The existing works (Busemeyer, Matthews, and Wang 2006; Pothos and Busemeyer 2009; Accardi, Khrennikov, and Ohya 2009; Khrennikov and Haven 2009; Aerts 2009; Yukalov and Sornette 2011; Busemeyer et al. 2011; see Busemeyer and Bruza 2014 for a review) models the problem in 2, 3 or 4-dimensional spaces. The author of this paper analyzed the PD game in 2D and 4D and compered these two options (Tesař forthcoming). We can say that the 2D model captures all the key findings of higher-dimensional models needed for this work.

Second, and most importantly, we made a substantial reduction of the quantum model by restraining to the vector space over the field of real numbers. The angles, which have been used to define and analyze the model, are not well-defined in the spaces over the field of complex numbers (see Scharnhorst 2001 for details). If we defined the angles e.g. as the Hermitian angle, the relation $\alpha = \beta + \gamma$, which is intuitive in the real vector space does not hold for the complex space. If so, how the findings presented above relates to the full-equipped quantum model? Recall that the probability of a choice has been defined as the square root of the orthogonal projection of the state vector and this entity was converted into the square root of the cosine or sine of the respective angle. We can revert this operation and e.g. the interval defined as $\beta \in (0°, \alpha)$ and $\gamma \in (\alpha, 0°)$ define simply as the other-perspectives in that $p(C|C') > p(C)$ simultaneously with $p(C') > p(C)$. It is evident that some possible options are missing in the Table 2. E.g. it is possible that, in the language of our toy model, $\beta \in (0°, \alpha)$ and $\gamma \in (0°, -\alpha)$ which is the situation 'on the border' of second and third row of the Table 2. This situation nevertheless corresponds to the cooperative normative as well as empirical expectation and is analogical to the second row of the table. All four possible combinations of the two expectations are present in the toy model and even though the full-scale quantum model is somewhat more complex, the toy model offers all possible outcomes.

To sum it, we can say that the 2D vector space over the field of real number was chosen to illustrate the quantum model with figures and the known mathematical concepts while conserving all the key aspects of the fully-equipped quantum model of the same situation.

Predictions of the quantum model

What does the quantum model predict for the observable behavior of the player in the strategic decision-making in the PD game? We have already shown this but to sum it up: 1) If the two perspective are non-compatible, quantum model predicts the presence of the order-effect, in other words, if players expect 'something different' from the others, their choice of strategies in self/other-perspective depends of the order of decision-making. 2) From that it follows that the overall willingness to cooperation is dependent on the before-present or non-present reasoning about the other-perspective. 3) Quantum model has higher degree of freedom than the classical model (in 2D it offers one additional free parameter). That means that also the prediction is not so concrete as in the classical model. Nevertheless from the symmetry of conditioned probability (e.g. $p(C|C') = p(C'|C)$) follows that quantum model of every dimensionality fulfills the so called *test of the reciprocity*, the q-test (Busemeyer and Bruza 2014, 104–5).

$$p(CC') + p(DD') = p(C'C) + p(D'D)$$

This is the parameter-free test, that can be used to test the model against the empirical results.

For the case of our experimental game we further assume that the two perspectives differ from each other only by a small angle β. We assume to find the game in a solution that belongs to the one of the first two rows of Table 2. In other words, that players are overly cooperative in the self-perspective and reasoning about the other-perspective make them more selfish (influence of the selfish norm) or they are overly selfish and the reasoning about the other-perspective make them more cooperative (compliance with the cooperative norm). How does these predictions hold up against the experimental results?

Results: Prisoners' Dilemma case

In this section I am going to present the main findings of one-shot PD game experiment, that took place at the Ohio State University in 2016. The experiment was online based and the players had no information about their opponents. Different players encounter the game in different treatment. Half of them made a decision in the self-perspective first (chooses their strategy) and then they specified their expectations, half of them decided the other-perspective first (expectations) and then chooses their strategy. All the choices were incentivized with a real money. For all the detail see (Tesař forthcoming), here I will review only the main findings relevant to the toy model of the game, which are summed in Table 3**Error! Reference source not found.**.

Table 3

	self-perspective first		other-perspective first	
Order effect	$p(CC')$	0.403	$p(C'C)$	0.246
	$p(CD')$	0.247	$p(C'D)$	0.145
	$p(DC')$	0.117	$p(D'C)$	0.174
	$p(DD')$	0.234	$p(D'D)$	0.435
Disjunction effect	$p(C)$	0.649	$p(C')$	0.391
	$p_T(C)$	0.420	$p_T(C')$	0.520
	$Int\ C$	-0.229	$Int\ C'$	0.128
Q-test	$p(CC') + p(DD')$	0.636	$p(C'C) + p(D'D)$	0.681
N. of players	N	77	N	69

What are the result regarding the predictions of the quantum model? First, the order effect: we see that the sequential probabilities (first four rows) are different in different orderings of perspectives. E.g. in the first row, 40.3% of players chose cooperation and then expected cooperation from their opponents, but this ration was only 24.6% when the expectation was decided first. The difference between the sequential probabilities is significant (χ^2=9.896, p=0.019).

Second, the disjunction effect: From the results, it is evident that the willingness to cooperate in the self-perspective (64,9%) is higher than the cooperation after considering the other-perspective (42,0%). The difference is 22,9% which is statistically significant (χ^2=7.689, p=0.006). The expectation about the others reveals a reverse effect. Players expects lower cooperation (39,1%) when asked first about their opponent but this number increases to 52,0% when the strategy of the player is reasoned beforehand (pattern well-described by Shafir and Tversky as the *wishful thinking* (Tversky and Shafir 1992; Shafir and Tversky 1992)). This effect is smaller and not significant (χ^2=2.408, p=0.121).

Third, the q-test. The sum of all matching choices equals 63.6% when players start with the other perspective, and 68.1% when the other-perspective goes first. The difference is 4.5% which is not significantly using a z-test of a difference between two probabilities (z=-0.5695, p=0.569).

The results support the quantum model of PD game as they follow the main prediction of this model. But what do the results say about the self/other-perspective interaction in regards to the social norms? If we take a closer look at the results, namely if we calculate $p(C'|C)$ as $p(C'|C) = p(CC')/p(C)$, we notice that the results exhibit the following pattern: $p(C) > p(C')$ and $p(C'|C) > p(C')$. I.e., in the language of our toy model, $\alpha < \gamma$ and $\beta < \gamma$. This is a familiar situation, known from Figure 4 and the first raw of the Table 2**Error! Reference source not found.**. We can improve the figure to account for the fact, that $p(C) \cong p(C'|C)$ a tedy $\alpha \cong \beta \cong \gamma/2$ and our toy model of PD game is as shown in Figure 5.

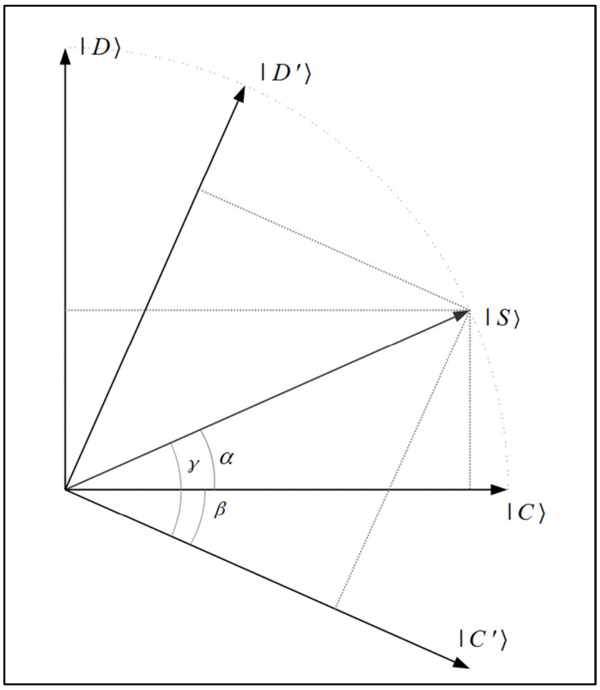


Figure 5

Overall, our interpretation of the PD game is as follows. The PD game is the sequential decision-making in the two mutually non-compatible perspectives. The player chooses if he/she stay in the self-perspective, or if he/she consider also the other-perspective. When players forced to start with the other-perspective, as in our experimental design, they significantly lower their level of cooperation consequently. There is the selfish social norm at play: Players expect significantly lower cooperation from the others and they follow it, because the perspectives are close enough to support that. These results are at odds with the standard interpretation of the PD game, which see rational players as selfish and the social norm (namely the cooperative social norm) as a tool that enables them to be more cooperative. We argue that the opposite is true: players 'by themselves' (in the self-perspective) are rather cooperative and it is their expectation of selfish others that make them selfish, conditioned by taking others into account.

Discussion

In the previous sections, we presented a quantum model of self/other-perspective interaction and tested it in the case of the one-shot Prisoner's Dilemma game. Available evidence is supportive to the quantum model – it can explain both the known 'fallacies' of human decision-making and the known features of the norm (non)compliance. Certainly, more experiments are needed to test the quantum model and the new experimental design to verify the robustness of our findings. The role of other parameters should also be examined. Our results e.g. show that women play the game in many aspects differently from men (Tesař forthcoming). We assumed that all players share both the same state vector and the mutual relationship of the two perspectives, which (at least between men and women) is not exact. Our intrinsic assumption was that the state vectors of the different players are well-distributed around some 'median vector' which is depicted in our figures, but the examination of the influence of the different hypothetical distributions will remarkable deepen our understanding of the real situation.

Before we have the stronger ground for the claims about the usefulness of the quantum model, there is no sense to theorize what would the acceptance of the model mean for our notion of rationality. But there are several partial aspects worth exploring.

First, one of the interesting features of the model is the situation where the other-perspective is rotated such that the state vector is identical with one of its basis vector (i.e. $\beta \in \{\alpha \pm 90°, \alpha\}$). In that case, the reasoning about the other-perspective makes no change in the state-vector. Therefore, the probability of both strategies in the self-perspective remains the same. In the other words, if the player would expect that all the others follow the same strategy there was no influence on his own choice, even if his state was widely different.

Second, the quantum model also gives a very specific place to the uncertainty. Players are to 'remove' the uncertainty about the others (to articulate their expectation) for the other-perspective have any influence. In the PD game, players lose their willingness to cooperate unless they stay uncertain about the others. It is the uncertainty that keep them cooperative. This should not be surprising as it corresponds to the experimental results (where players 'learn' to defect in repeated games by learning the other strategies) and the common sense as well. It indirectly supports the quantum model.

Third, our analysis of the beta angle show also remarkable features that are analogical to the process of identity formation. We saw, that small betas correspond to the 'closeness' of perspectives which leads the actors to follow the others. On the contrary, large betas correspond to the 'protest view' that leads them to revolt and go against the others. It could correspond to the benign or malign others that form the player's identity in the process of identifications with (or against) the significant others.

Quantum models of decision-making are certainly somehow inaccessible for their unfamiliar math. Our aim in this paper was to introduce the toy model that can show how it can improve our understanding of the problem of the social norm compliance. The features of the quantum model are nevertheless not something new. They follow the patterns known from the experimental results, and often the common sense too.

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[i] More precisely in the vector space above the field of complex numbers. I.e. in the coordinate representation the coefficient in the linear combination are complex numbers.

[ii] For the consistency with the above-mentioned literature I use here the Dirac symbolic. The symbol $|A\rangle$ denotes the column vector which number of rows corresponds to the dimension of the respective Hilbert space.

[iii] If alpha were outside the defined interval, we can simply switch the vectors $|C\rangle$ and $|D\rangle$ in our analysis and findings will remain the same.

[iv] Here we follow the convention to define the angles as positive in the counter-clockwise direction and negative in the clockwise direction.

[v] Our analysis is constrained to the open intervals. But what is the situation at the border values, for $\beta = \{0°, \alpha, 2\alpha, 90°\}$? From the Table 2 is evident that these are the values where there is the change of the direction of the other-perspective's influence. I.e. in these values of β the impact of the other-perspective is neutral.