Worlds of Entanglement Book of Abstracts

WOE Organizing Committee

29-30 Sept 2017

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2 Abstracts

2.1 Quantum Foundations

2.1.1 On the role of entanglement in quantum information and beyond, Marcus Huber

On the role of entanglement in quantum information and beyond
Marcus Huber
IQOQI, Vienna, Austria.

Entanglement is a phenomenon at the heart of quantum physics that has wide-reaching implications for communication, computation and more generally the foundation of many-body physics. In this talk I will give an introduction into the definition, meaning and implications of entanglement in quantum information theory and beyond. I will furthermore present how it can be efficiently certified in state of the art quantum experiments and how it enables a paradigm of device independent experiments that let us test the structure of physical theories beyond specific models.

2.1.2 On the Conceptuality interpretation of Quantum and Relativity Theories, Massimiliano Sassoli de Bianchi

On the Conceptuality interpretation of Quantum and Relativity Theories
Massimiliano Sassoli de Bianchi
Laboratorio Autoricerca, Lugano, Switzerland.

How can we explain the strange behavior of quantum and relativistic entities? Why do they behave in ways that defy our intuition about how physical entities should behave, considering our ordinary experience of the world around us? In this talk, I will address these questions by showing that the comportment of quantum and relativistic entities is not that strange after all, if we only consider what their nature might possibly be: not an objectual one, but a conceptual one. This not in the sense that quantum and relativistic entities would be human concepts, but in the sense that they would share with the latter the same conceptual nature, similarly to how electromagnetic and sound waves, although very different entities, can share the same undulatory nature. When this bold hypothesis is adopted, i.e., when Diederik Aerts’ conceptuality interpretation is taken seriously, most of the interpretational difficulties disappear and our physical world is back making sense, though our view of it becomes radically different from what our classical prejudice made us believe.

2.1.3 Dark physics and non-Diophantine arithmetic, Marek Czachor

We don’t know where dark energy comes from, and what is its fundamental origin. One of the possibilities is that its apparent presence is just a manifestation of a miss-match between the mathematics employed by "us", and the one "employed" by the Universe. Another possibility is that dark energy
comes from sets of measure zero, overlooked by the Hilbert-space formalism of quantum mechanics. In both cases, the formalism that naturally grasps the phenomena starts with a more general definition of arithmetic. The arithmetic is non-Diophantine, which means it does not follow all the rules formalized by Diophantus of Alexandria.

2.1.4 Breathing in and out of individuality and entanglement, Karl Svozil

As already Schrödinger pointed out in his famous "cat"-series of papers, in quantum mechanics multiple particles can be in a totally defined state globally, whereas the individual states of its constituent particles remain totally undefined. Indeed, states of multiple particles, even if they are totally defined as the product states of individual particles, are just a unitary transformation – that is, an isometry (a distance preserving bijection, that is, a one-to-one transformation) – away from total entanglement; and \textit{vice versa}. Thereby, information can neither be gained nor destroyed. One could, for instance, easily construct two unitary operators in four dimensions – an “entangler” and an “individuator” – which rotate a pure non-entangled state cyclically back and forth into states corresponding to the entangled Bell and non-entangled Cartesian bases, respectively; just like breathing in and out of collectivism and individuality. All this is a rather trivial consequence of the fact that arbitrary pure states of multiple particles are just coherent superpositions of their product states. What is less trivial though is the fact that the quantum probabilities, with the exception of a few isolated points, demand stronger-than-classical correlations; a fact which is often interpreted as giving rise to \textit{a posteriori} “nonlocality.”

2.1.5 Quantum Superpositions and the Representation of Physical Reality Beyond Measurement Outcomes and Mathematical Structures, Christian De Ronde

Consejo Nacional de Investigaciones Científicas y Técnicas, CONICET

In this paper we intend to discuss the importance of providing a physical representation of quantum superpositions which goes beyond the mere reference to mathematical structures and measurement outcomes. This proposal goes in the opposite direction to the project present in orthodox contemporary philosophy of physics which attempts to bridge the gap between the quantum formalism and common sense classical reality precluding, right from the start, the possibility of interpreting quantum superpositions through non-classical notions. We will argue that in order to restate the problem of interpretation of quantum mechanics in truly ontological terms we require a radical revision of the problems and definitions addressed within the orthodox literature. On the one hand, we will discuss the need of providing a formal redefinition of superpositions which captures explicitly their contextual character. On the other hand, we will attempt to replace the focus on the measurement problem, which concentrates on the
justification of measurement outcomes from weird superposed states, and introduce the superposition problem which concentrates instead on the conceptual representation of superpositions themselves. In this respect, after presenting three necessary conditions for objective physical representation, we will provide arguments which show why the classical (actualist) representation of physics faces severe difficulties to solve the superposition problem. Finally, we will also argue that, if we are willing to abandon the (metaphysical) presupposition according to which Actuality = Reality, then there is plenty of room to construct a conceptual representation for quantum superpositions.

2.1.6 Indefinite causal order in quantum mechanics, Ognyan Oreshkov

Indeﬁnite causal order in quantum mechanics
Ognyan Oreshkov
ULB, Brussels, Belgium.

Quantum mechanics teaches us that physical variables in general do not have deﬁnite values unless measured. Yet, the time and causal order of events in quantum mechanics are assumed deﬁnite. A natural question is whether the latter reﬂects a fundamental physical restriction or it is an artefact of our formulation of the theory. Is it possible that, in suitable circumstance, the causal order of events can be indeﬁnite similarly to other physical variables, and what would it take to demonstrate this? Recently, we investigated this question from the standpoint of a new framework for quantum mechanics, which does not assume a causal structure from the outset. This framework uniﬁed all correlations between local quantum experiments in space-time via a mathematical object called the process matrix, which generalises the standard density matrix. Remarkably, the framework also revealed the in-principle possibility for a new kind of correlations incompatible with any deﬁnite causal structure. These correlations violate causal inequalities. The question of whether this phenomenon has a physical realisation, however, has remained open. In this talk, I will propose an affirmative answer to this question.

2.2 Quantum Beyond Physics
Accumulating paradoxical findings in cognitive psychology reveal that classical set-theoretic structures are generally unable to model human judgments and decision-making under uncertainty. This makes problematical the interpretation of a wide range of cognitive phenomena in terms of (Boolean) logic and (Kolmogorovian) probability theory. The experimental literature has identified in the last forty years two types of “deviations from classicality” in cognition, namely, ‘probability judgment errors’ and ‘decision-making errors’. The former include over/under-extension effects in conceptual combinations, conjunctive and disjunctive fallacies, e.g., the ‘Linda problem’. The latter include the disjunction effect and violations of expected utility theory in concrete decisions, e.g., the ‘Allais’, ‘Ellsberg’ and ‘Machina paradoxes’. Starting from the nineties, the application of the mathematical formalism of quantum theory has been successful to model these empirical deviations from classicality, which Tversky and Kahneman attributed to ‘fallacies of human reasoning’.

Relying on a two-decade research on the operational and realistic approaches to quantum physics and quantum probability, we present here the foundations of the “quantum cognition” research programme. We firstly illustrate the success of a quantum-theoretic framework in the modeling of combinations of natural concepts, showing that membership judgment errors, like over/under-extension, can be explained in terms of genuine quantum effects, i.e. ‘contextuality’, ‘entanglement’, ‘interference’, ‘quantum indistinguishability’ and ‘superposition’. Then, we apply the quantum-theoretic framework to decision-making errors, and put forward a specific non-Bayesian extension of expected utility theory in which subjective probabilities are represented by quantum probabilities, while the preference relation between acts depends on the state of the situation that is the object of the decision. We show that the quantum-theoretic framework allows modeling of the Ellsberg and Machina paradox situations and, more generally, representation of individual attitudes toward uncertainty. The quantum-theoretic framework is a first step toward the development of a ‘state-dependent non-Bayesian extension of EUT’, and has potential applications in economic theory, which we briefly sketch.
Quantum mechanics is the weirdest of sciences that allows particles to inhabit multiple locations in space and time at once, travel through classically-impenetrable barriers and possess spooky connections across vast regions of space. Yet the science is usually considered to be limited to the tiniest components of matter, such as protons or atoms. As systems get bigger, classical behaviours in which particles tend to be in one place or another, cannot penetrate impenetrable barriers and are not spookily connected, tends to dominate. However, several decades ago, one of the founders of quantum mechanics, Erwin Schrödinger, proposed in his book, What is Life? published in 1944 that “a gene or perhaps the whole chromosome fibre (is) an aperiodic crystal (in which) every atom, and every group of atoms, plays an individual role which has to be a masterpiece of highly differentiated order, safeguarded by the conjuring rod of quantum theory.” He went on to claim that life was fundamentally quantum mechanical. In this talk I will examine Schrödinger’s claim from the perspective of modern quantum biology and molecular biology. I will discuss evidence for the quantum tunnelling, quantum coherence and even quantum entanglement a wide range of biological phenomena such as avian navigation, enzyme action, photosynthesis, the sense of smell and mutation. I will also discuss advances in relation to that most fundamental question of biology: what is life?

The non-summability of visual perception, Jonito Aerts

We analyse the way in which the principle that the whole is greater than the sum of its parts manifests itself with phenomena of visual perception. For this investigation we use insights and techniques coming from quantum cognition, and more specifically we are inspired by the correspondence of this principle with the phenomenon of the conjunction effect in human cognition. We identify entities of meaning within artefacts of visual perception and rely on how such entities are modeled for corpuses of texts such as the webpages of the World-Wide Web for our study of how they appear in phenomena of visual perception. We identify concretely the conjunction effect in visual artefacts and analyse its structure in the example of a photograph. We point out how this approach can lead to a mathematical description of the meaning content of a visual artefact such as a photograph.
2.3 Entanglement in Social Sciences

2.3.1 The Politics of Ontology: Resistance to Quantum and Quantum as Resistance, Alexander Wendt

My 2015 book, Quantum Mind and Social Science, argues for a realist as opposed to metaphorical interpretation of quantum social science that human beings really are “walking wave functions.” This claim has proven particularly controversial, and prompts these reflections on the politics of social ontology. In the first part of my talk I briefly discuss various reasons why people might not just disagree with, but disagree vehemently with, a realist view of quantum social science. Psychological defense mechanisms against new ideas and sociological pressures to maintain orthodoxies are obvious causes, but I think there are also deeper, if unconscious, political forces at work here. In the second part of the talk I explore the latter in more detail, focusing particularly on pedagogy at the both elementary and graduate school levels. Much like learning economics has been shown to make college students more selfish and individualistic, I suggest that being socialized to the classical worldview as a way of thinking about social relationships produces a kind of distorted, truncated subjectivity. Classical subjects have learned to mostly repress their natural, quantum selves, and that in turn enables states to make their citizens more calculable, manageable, and thus capable of mobilization for state projects. Metaphorical readings of quantum social science do not challenge this political hegemony; realist ones would. Embracing the latter is therefore a form of resistance to the established order.
A bold metaphysics for the social sciences

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and
Matteo Scozia (University of Calabria, mt.scozia@gmail.com)

Abstract for the session on the Social Sciences and Philosophy

This paper starts from two, related sources. The first source is Alexander Wendt’s claim in the final chapter of his recent book that, given the quantum mind hypothesis, the state as such is “only a potential reality, not an actual one”, which can materialize momentarily “in daily affairs such as voting, paying taxes, and going to war, and then disappearing again.” (Wendt 2015, 268) The second source is Axel Schmidt’s discussion of the connections between the thoughts of John Duns Scotus and contemporary quantum physics (Schmidt 2003). An important element in that discussion is Scotus’s radicalization of the metaphysics of contingency needed to understand human (and divine) freedom, which led to his discovery of synchronic contingency whereby free agents have open alternatives at one and the same instant of time.

This paper explores how a metaphysics of dispositional realism – as developed in contemporary analytic metaphysics, but retrieving the Aristotelian act-potency distinction – can connect Scotus’s synchronic contingency to the kind of metaphysics of social reality proposed by Wendt. Although the connection between quantum theory and the Aristotelian notion of potency was already recognized by Heisenberg (Heisenberg 1962; Suárez 2007), Wendt only briefly considers these interpretations because he finds that they “as such do not capture the phenomenology of mental causation or willing.” (Wendt 2015, 121). However, Scotus notably developed the Aristotelian position on potency precisely on the issue of willing (Scotus and Wolter 2000). Although no ready-made sociological ontology is available in or derivable from Scotus, key elements in his thinking will be used to develop a social ontology compatible with, or at least congenial to, Wendt’s proposal.

The basic hypothesis is that if human beings are free in the sense of having metaphysically robust alternative possibilities for action at one and the same instant of time, then social reality is irreducibly more ‘dense’ than what is at any one instant of time actual in terms of the current practices of people. What they can do or could have done instead of what they did or are doing is a necessarily irreducible aspect of whatever currently actualized choice, and the metaphysics of social reality is therefore to a large extent a metaphysics of this unactualized realm of potential alternatives. It is a metaphysics of unmanifested powers or dispositions – cf. Wendt’s idea of social structures as “pure potentialities” (Wendt 2015, 258) – which stands in certain necessary relationships with the actualized or manifested practices and decisions. These relationships are differentiated by their compossibility and concatenation with other potentialities as well as with their actualized counterparts.

A first social-scientific application would be in the field of comparative institutional analysis. Institutions qua social structures are powers or potentialities, but their specific dispositional profiles are synchronically contingent upon the continued and will of the persons involved to follow their deontic profile of rights, obligations, etc. A rash conclusion would be that since the continued existence of any political structure is at any time contingent, the attainment of any alternative political or societal structure is possible. Or, more radical still, any societal structure at all might perceived as an unjustifiable suppression of incompossible alternatives. However, the aspect of necessity introduced by institutions not only constrains the initial set of alternatives open to persons, but also drastically enlarges their set of alternative possibilities by enabling concatenations with the actions and possibilities of billions of anonymous people. Moreover, different institutional set-ups exhibit different dispositional profiles, thereby enabling and constraining societies in different ways for actualizing a certain degree of societal perfection. A key research question is then which institutional profiles ‘minimally’ constrain and ‘maximally’ enable the individuals or societies involved in relation to these different degrees of societal perfection.

A second social-scientific application would be in economics. For a start, institutional economics can be tied in with the previous application as exploring the different degrees of economic prosperity certain institutional set-ups enable or constrain. Moreover, as argued by Hülsmann in relation to the possibility of economic laws given free human choice (Hülsmann 2003), economic laws do not primarily address the relations between successive points in time, but between synchronous points at one instant in time, by comparing a certain choice with its real though potential alternatives that are not actualized. Economics as framed within a fixed institutional structure therefore studies the dynamics of the synchronous choices made by countless persons as their concatenations and incompossibilities mutually impact the possible choices and degree of prosperity of other persons involved. Phenomena like savings, investment, capital, consumption, profit and loss can then be understood as differentiations within a realm of potential courses of action, actualizing different degrees of economic perfection or prosperity.

Bibliography


2.3.3 The entanglement of the social realm: Towards a field theory approach of the social sciences, Luk Van Langenhove

The entanglement of the social realm: Towards a field theory approach of the social sciences
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This paper presents the outline of an ontology of the social realm that aims to provide a new perspective to the study of psychological and social phenomena. The presentation draws upon the authors work with Rom Harré on positioning theory as well as on his experiences with interdisciplinary research in the social sciences. See amongst others: Van Langenhove (2007, 2011, 2017). It will be argued that in order to raise the impact of the social sciences, research should start from a new ontological perspective that puts discourse and practices central. Rather than dividing the social and psychological realm into different disciplines, the perspective should be that the social and the psychological need to be regarded as two sides of the same coin. And, that not space and time should be the primary referential grid for the social sciences but conversations and people. Within this perspective the substance of the social realm can be regarded as a species-wide and history-long web of conversations between people (and other actors with personhood properties) in which ideas and speech-acts can be regarded as the basic forces that create agents and structures. The power of speech-acts is in essence non-local: it does not matter much where and when they are uttered, but rather by whom and in which conversational contexts they are uttered. This can be captured by the metaphor of social entanglement where social events have particular bonds that transcend space and time. The agents that emerge out of conversations are on the one hand persons and institutions that can act as if they are persons. The structures can be regarded as non-local fields of both knowledge orders and moral orders that influence what actors can and should do. A typology of moral orders, based upon the Positioning Theory approach (Harré and Van Langenhove, 1999) will be presented that allows to integrate insights in the functioning of societies, institutions and practices with how persons cope with everyday life. The paper will end with a brief presentation of the methodological implications of such a new ontological perspective for the social sciences.

References.
2.3.4 Social foundations: The quantum-like physics of interdependence for teams, William Lawless

Social foundations: The quantum-like physics of interdependence for teams
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Abstract:
Despite the promise of the cognitive revolution for human understanding, based on self-reports between cognitive constructs and actual behavior, the result has been variances at meaningless levels (Zell & Krizan, 2014), leaving little to guide the engineering of hybrid teams consisting of humans, machines and robots. Oppositely, rejecting subjectivity has led to limited success for the physical science of networks (Liu & Barabási, 2016), but with no room for intelligence. In contrast, by adopting quantum-like models for the physics of interdependence combining subjective and physical aspects in a mathematics of teams, we have found evidence in the field for the second law of thermodynamics and the application of intelligence in our solution to the open problem of team size (Lawless, 2017b).

Interdependence characterizes the best teams (Cummings, 2015). However, the measurement of interdependence makes replication impossible (Lawless, 2017). Removing interdependence in social experiments improves replicability (e.g., Kenny et al., 1998). But the cost is an absence of mathematical building blocks in the social sciences; the lack of mathematics in the science of team science; and the open problem of team size (e.g., Cooke & Hilton, 2015, p. 33). Yet, removing interdependence is tantamount to considering quantum effects “pesky” in the study of the atom.

How to aggregate individual contributions of team members? Traditionally, Centola & Macy (2007, p. 716) speculated that redundancy improves team efficiency. However, Cummings (2015) reported that the worst performing scientific teams were interdisciplinary, implying interdisciplinarity reduces interdependence.

By using quantum-like models and Kullback-Leibler divergence (Lawless, 2017), we found firms in free markets had less redundancy than those under authoritarian governments; e.g., compare Sinopec’s 124.6 employees/M BBL of oil produced with Exxon’s 15.5, illustrating that redundancy creates inefficiency. Based on this success, we predicted that, like entanglement at the quantum level, interdependence makes teams more competitive (e.g., Powell, 2017).

We replicated this finding by comparing a distribution of economic freedom versus the size of a nation’s military with another distribution for corruption versus the size of a nation’s military (Lawless, 2017b). As we theorized, interdependent teammates are responsive to each other as a team multitasks to compete.

With Fourier pairs adapted from Cohen (1995), our model of interdependence between actions versus observations, dissonant beliefs or competing teams becomes:

\[ [A, B] = iC \rightarrow \sigma_A \sigma_B \geq 1/2 \]

i.e., the exact knowledge of the standard deviation for factor \( A \) (\( \sigma_A \)) precludes simultaneously the exact knowledge of factor \( B \); e.g., from Arrow (1951/1963), aggregating preferences of three or more independent individuals is impossible without majority rule or dictatorial decision, but humans easily aggregate by self-organizing into teams (Lawless, 2017), suggesting that interdependent teammates aggregate complementarily (unlike Shannon’s slaves, orthogonality implies the beliefs for \( A \) and \( B \) become: \( A \ast B = 14 \cos90 = 0 \)). Traditional aggregation occurs by
summing degrees of freedom among independent agents, i.e., $\sum n_{individuals} \sim dof$. Compared to the destructive interference from a dysfunctional team that makes its members act like individuals, if instead the perfect team acts as a single unit like a crystal, in agreement with the second law of thermodynamics, team fit becomes critical, suggesting $dof_{team} \rightarrow 1$ for their shared determination to solving a dedicated problem, giving for their structural entropy:

$$\log(dof_{perfect\, team}) \leq \log(dof_{dysfunctional\, team}) \quad (2)$$

From Eq. 2, as redundancy increases a team’s $dof$, team performance deteriorates, motivating our speculation to revise Eq. (1) to the standard deviation of entropy produced by team structure (least entropy production, or LEP) times that for team performance (maximum entropy production, or MEP):

$$\sigma_{LEP} \sigma_{MEP} \geq 1/2 \quad (3)$$

implying that $\lim_{\sigma_{LEP} \rightarrow 0} \sigma_{MEP} \rightarrow \infty$; i.e., the best performing teams use their collective intelligence to overcome barriers with constructive interference that minimizes effort on team structure (Wissner-Gross & Freer, 2013), maximizing MEP for missions (Martyushev, 2013). In contrast, illuminated by a perturbation (e.g., competition), a dysfunctional team reverses Eq. (3):

$$\lim_{\sigma_{MEP} \rightarrow 0} \sigma_{LEP} \rightarrow \infty; \text{ i.e., a dysfunctional team generates maximum entropy tearing its structure apart, impairing its competitiveness.}$$

For future research, if teammates are characterized as intelligent things, whether humans, machines or robots, as a key step in the engineering of teams, we expect to find that larger team structures generate more entropy (i.e., more arrangements are possible), requiring proportionately more energy to cohere; that perfect teams operate at stable, ground states, dysfunctional teams at excited, emotional states; and that entropy for a perfect team is subadditive (i.e., $S(\rho_{AB}) \leq S(\rho_A) + S(\rho_B)$; Von Neumann subadditivity occurs mindfully, we speculate, with superposition of the terms from interference), an information loss from maximum interdependence (precluding the replication of a perfect team, similar to no-cloning; e.g., Wooters & Zurek, 2009, p. 77), while the information from a dysfunctional team increasingly gains Shannon information to inadvertently clarify context ($H(x,y) \geq H(x) + H(y)$), the two forming a metric for team performance.

References:


2.3.5 Quantum World Society, Mathias Albert

Quantum World Society
Mathias Albert
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The presentation introduces the concept of world society as a complex social system (1), then argues how this could be linked to and benefit from quantum thought, particularly through the linking concepts of observation and entanglement (2); The presentation then will elaborate on hints that there have been traces of ‘quantum thought’ in social theory and philosophy even before quantum theory in the natural sciences (3), and conclude by offering a view thoughts on a programme for further entangled engagements.

2.4 Complex Systems

2.4.1 Learning and Inference in Complex Networks, Tina Eliassi-Rad

Learning and Inference in Complex Networks
Tina Eliassi-Rad
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Complex networks are ubiquitous in part because they effectively represent social, physical, biological, and technological phenomena. Machine learning algorithms operating on complex networks exploit the relational dependencies present in such data. In this talk, I will present the problem of node classification in complex networks, draw analogies to the entanglement phenomenon, and discuss state-of-the-art solutions from statistical relational learning and semi-supervised learning.
2.4.2 Entanglement through semiosis? Towards measuring a physical media’s potential to implement codes as contingent mappings, Peter Dittrich

This contribution discusses a potential link between entanglement and semiosis, that is, the emergence and processing of meaningful signs. In semiotics, describing a sign process usually involves three objects: a sign representation, the meaning of a sign, and an interpreting context; which are thought of being non-separable. Sign and meaning are linked, but not in a classical physical way, i.e., there is no energetic or material link, and the relation cannot be inferred from looking at the sign or its meaning alone. This contingent (or, arbitrary) relation between sign and meaning has been stressed as an essential feature of biological molecular information processing (Monod 1971, Barbieri 2008).

In order to get the notion of semiosis closer to the realm of physics a formal method to assess the semantic capacity of a physical media to process "meaningful" information is presented (Dittrich 2017). It has been originally introduced for chemical reaction systems (Görlich&Dittrich 2013) and will be demonstrated here also for elementary cellular automata (ECA), serving as an abstract model of a physical medium. The basic idea is to measure how easy it is to implement with the medium (e.g., a chemical reaction network) a molecular code, which is a contingent mapping between species, that is, a mapping that cannot be inferred from knowing the species and the medium alone. A preliminary computational analysis of various chemical systems revealed a quite large spectrum of different semantic capacities. Basically no semantic capacity was found in a model of the atmosphere photo-chemistry of Mars and four studied models of combustion chemistries, whereas bio-chemical systems posses very high semantic capacities. From this, the hypothesis has been derived that over the course of evolution life is gaining access to (chemical) systems with increasing semantic capacity.

So far, the models considered (reaction networks and ECAs) are discrete and deterministic systems that are not designed to model quantum entanglement. In the final part of this contribution this fact will be critically caved out and discussed how entanglement can be linked to (molecular) semiosis and the idea of molecular codes and contingent mappings.

References
Dittrich, P. 2017. Towards measuring the semantic capacity of a physical medium demonstrated with elementary cellular automata (submitted).
2.4.3 An Information-Geometric Approach to Complexity, Nihat Ay

An Information-Geometric Approach to Complexity

Nihat Ay
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I will present an information-geometric approach to complexity. This approach is based on the general understanding that the complexity of a system can be quantified as the extent to which it is more than the sum of its parts. I will motivate this approach and review corresponding work for probability distributions, stochastic processes, in particular Markov chains, and density matrices. Within the latter context, complexity turns out to be closely related to quantum entanglement.

2.4.4 Distributed organization in complex adaptive systems, Francis Heylighen

The Latin word “complexus” can be translated as “entwined” or “entangled.” Thus, a complex system can be seen as consisting of distinct components that are interconnected in such a way that they cannot really be separated or treated independently. Classical Newtonian science is poorly equipped to deal with such systems, because it analyses or reduces systems to their independent elements. Complexity science has begun to address the issue by studying how interactions between active components (agents) can give rise to emergent organization. Thus, living organisms emerge from networks of chemical reactions, consciousness from networks of interacting neurons, and society from interacting individuals. Such organization is distributed, in the sense that it is not a property localized in particular components or agents, but a pattern of coordination between the actions of all the agents. Thus, agents and their activities are “entangled” with other agents. The talk will introduce action ontology and the notion of “chemical organization” as foundations for modelling such emergent organization, and as a replacement for the static, materialistic and reductionist Newtonian ontology. It will also briefly describe a number of applications such as self-organization, autopoiesis, social systems and distributed intelligence.
ABSTRACT:

Quantum Logic, Chaos, Bayesian Inference & Complex Systems

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The violation of Bell-type inequalities in cognitive and psychological tests and tasks has long been established within the achievements of the scientific field of Quantum Cognition. Much is owed to the pioneering and seminal work of Aerts from 1995 till now. Nowadays, quantum-like behavior in language, concept correspondence and operational research and decision making have been developed in several publications by a considerable and fast growing community of authors (some of the fundamentals can be found in the books by Svozil [1], Busemeyer and Bruza [2], Khrennikov [3]).

Ambiguous figures have been used to detect and analyse the violation of classical probability during their perception/recognition by human subjects. Quantum probability rather than classical probability rules seems to rightfully apply in this dominion of perception [4, 5]. Moreover, ambiguous figures have been acknowledged as an important observational gateway to the workings of the brain when perception changes but not the stimulus. And seemingly it is hard to find any two more “entangled” concepts than the pair of the “inside-out” perception of the Necker cube, for example. Indeed, quantum probability at work has been discovered via the utilization of the K-test (temporal version of a quantum Bell test, by Leggett and Garg) [4] and a “decoherence” or de-correlation time, compatible with the short term memory windows given by other experiments on linguistic understanding was established.

Notably, the recognition of ambiguous figures can also be understood, in the realm of biological information processing, as the symmetry breaking of a bistable potential. The class of dynamical processes in biological information processing is understood as that of “chaotic itinerancy” which entails the creation, modification and annihilation of attractors during two phases (the exploration phase, expansion of the phase-space, positive sum of Lyapunov exponents, generating information; and the categorization phase, contraction of the phase-space, negative sum of Lyapunov exponents, compressing and storing information. For a review see [6, 7].

In our previous work we propose a synthesis of these two ways of understanding using a generic model; and through its mathematical analysis we show that it follows a quantum-logical structure. [7, 8, 9]. Our model implements the dual process of
Bayesian and Inverse-Bayesian inference (Bayesian inference contracts probability space, while inverse Bayesian inference relaxes this space).

Our generic model [8,9] is neural networks of the “restricted Boltzmann machine” class, a generalization of the classic Hopfield model, chosen due to its generality as a universal computing scheme and its wide use in many areas. Moreover restricted Boltzmann machines have been shown to be compatible with (but not reducible to) the so called Global Workspace Hypothesis (GWS) in neuroscience.

Within our scheme these two inferences allow an agent to make decisions corresponding to immediate changes in their environment. They generate a particular pattern of joint probability for data and hypotheses, comprising multiple diagonal and noisy matrices. This is expressed as a nondistributive orthomodular lattice equivalent to quantum logic. We also show that an orthomodular lattice can reveal information generated by inverse syllogism as well as the solutions to the frame and symbol-grounding problems. Our model serves to connect macroscopic cognitive processes with the mathematical structure of quantum mechanics with no additional assumptions.

Selected References:


2.5 Quantum Artificial Intelligence

2.5.1 Information Access and Retrieval Meets Quantum Mechanics, Massimo Melucci

Information Access and Retrieval Meets Quantum Mechanics
Massimo Melucci
Computer Science Department, University of Padova, Italy

When facing a problem, everyone needs information and searches out the most relevant information to her needs. Due to the big amount of users, needs and data, computerized methods are unavoidable. Information Retrieval (IR) is the science to design and engineer systems that represent and retrieve all and only relevant information in any context (perfect retrieval). However, what a user assesses as relevant at a certain time, in a certain location or with a certain intent will differ from what is relevant to another user, at another time, in another location, with another intent.

Relevance cannot exactly be measured outside context unlike other less context-sensitive observables (e.g. pertinence). If relevance can be measured only in a given context, other observables may interfere. E.g., IR is based on classical probability, thus events are as subsets of a single sample space. This implies that the probability of an event A (e.g. relevance) can never be less than the probability of the conjunction of A with another event B (e.g. pertinence). However, violations of this law have been found in empirical studies, but “disappears” in quantum probability.

For 15 years, Quantum Mechanics (QM) has also been investigated in human cognition, natural language processing and IR among others. Many questions are still outstanding. Can perfect IR be achieved by QM? Should modalities (e.g. image clicking) be modeled addressed by classical probability as done for words? Will context create a major shift in how probability is viewed within information retrieval? Constructing classical probabilistic models involves joint probability distribution over variables. Does this joint distribution always exist? These issues are under investigation within an EU MSCA-ITN project coordinated at DEI (www.quartz-itn.eu).

2.5.2 Quantum-enhanced algorithms in machine learning and AI, Peter Wittek

Quantum-enhanced algorithms in machine learning and AI
Peter Wittek
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We see more and more applications of quantum information processing and the recent progress in building scalable universal quantum computers is remarkable. Machine learning and AI comprise an important applied field where quantum resources are expected to give a major boost. On a theoretical level, we can ask what ultimate limits quantum physics imposes on learning protocols. To answer
this, we need to generalize classical results such as structural risk minimization and model complexity, and no-free-lunch theorems. On a more practical level, we can study potential speedups of quantum-enhanced protocols, which range between exponential and quadratic reduction in complexity. Finally, we may consider what can be implemented with current and near-future technology, particularly when it comes to computationally expensive algorithms such as probabilistic graphical models. Even a constant-time speedup can enable these models the same way graphics processing units enabled deep learning, and this promise is already seeding a new wave of startup companies.
2.5.3 A Quantum-inspired approach to Pattern Recognition, Giuseppe Sergioli

A Quantum-inspired approach to Pattern Recognition

Giuseppe Sergioli
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ABSTRACT

Quantum mechanics is a probabilistic theory that turns out to be successfully predictive with respect to a wide range of microscopic phenomena. Given an arbitrary state and a certain perturbation, quantum mechanics makes a probability distribution to obtain a possible value of a given observable. The quantum mechanical formalism is particularly suitable to describe different kinds of stochastic processes, that - in principle - can also include non-microscopic domain. In recent years a number of non standard applications of the quantum formalism has arisen. For example, the quantum formalism has been widely used in game theory [5, 11], in the economic processes [12] and in cognitive sciences. Concerning this domain, Aerts et al. [1, 2, 3, 4] have shown some non-trivial analogies between the mechanisms of human behavior and the ones of the microscopic systems.

By this perspective, another non-standard application of quantum theory is devoted to apply it for solving classification problems. The basic idea is to represent classical patterns in terms of quantum objects, with the aim to boost the computational efficiency of the classification algorithms. In the last few years many efforts have been made to apply the quantum formalism to signal processing [6] and to pattern recognition [13, 14]. Exhaustive surveys concerning the applications of quantum computing in computational intelligence are provided in [10, 17]. Even if these approaches suggest possible computational advantages of this sort [8, 9], what we propose here is a different approach that consists in using quantum formalism in order to reach some benefit in classical computation. Indeed, this have already addressed in a recent works [7, 15], where a “quantum counterpart” of a the Nearest Mean Classifier (NMC) has been proposed. This proposal has been constructed on the following basis:

i) first, an encoding of an arbitrary two-feature pattern into a density operator on the Bloch sphere has been presented;

ii) then, a concept of “quantum centroid” that plays a similar role as the classical centroid in the NMC has been introduced;

iii) finally, a distance measure between density operators that plays a similar role as the Euclidean distance in the NMC has been proposed.

It has been shown (in [15]) that this quantum counterpart of the NMC - named quantum NMC (QNMC for short) - leads to significant improvements for several 2-feature datasets.

In this talk we propose an alternative version of the QNMC, where another encoding of real vectors (n-feature patterns) into density operators is involved. The problem to encode real vectors by quantum objects is not trivial and it could turn out to be promising for the whole theory of machine learning. Quoting Petruccione: “In order to use the strengths of quantum mechanics without being confined by classical ideas of data encoding, finding “genuinely quantum” ways of representing and extracting information could become vital for the future of quantum machine learning” ([16], pg.6).

We will show how the new proposed encoding leads to two relevant advantages: i), unlike the old encoding, it allows us to extend the classification model to n-feature patterns in a very natural way; ii) it improves the efficiency of the QNMC. In the final part of the talk we also focus on a very considerable difference between the NMC and the QNMC: unlike the NMC, the QNMC is not invariant under rescaling. More precisely, the accuracy of the QNMC changes by rescaling (of an arbitrary real number) the coordinates of the dataset. This seeming shortcoming turns out to be partially beneficial to the classification process.
REFERENCES

2.6 Uncertainty in Economics

2.6.1 Decisions under uncertainty on theories and facts, Massimo Marinacci

Decisions under uncertainty on theories and facts
Massimo Marinacci
Department of Decision Sciences of Bocconi University, Italy.

We present an analysis of decision problems that takes into account the model uncertainty that often arises because of scientific and measurement concerns.

2.6.2 Robust animal spirits in a small open economy, Jocelyn Tapia

This work extend the Schmitt-Grohé and Uribe (2003) model for an small open economy considering that agents are endowed with robust preferences concerned about model misspecification. In this framework, it will be analyzed the effects of domestic and external shocks when agents take decisions according to the worst case probabilistic scenario.
Quantum-Like Influence Diagrams: Incorporating Expected Utility in Quantum-Like Bayesian Networks

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It has been established in the literature that quantum-like models provide an alternative way of explaining and accommodating paradoxical findings that are unexplainable through classical probability models (Busemeyer and Bruza, 2012; Bruza et al., 2015)

Quantum-like models tend to explain the probability distributions in several decision scenarios where the agent (or the decision-maker) tends to act irrationally. By irrational, we mean that the agent chooses strategies that do not maximize or violate the axioms of expected utility. However, it is not enough to explain these irrational decisions through probability distributions. It would be desirable to use these probability distributions to help us act upon a real world decision scenario. For instance, it is not enough for a doctor to find out the disease of a patient. The doctor needs to decide which treatment to give to the patient, based on the disease and on the patients tolerance towards different medications.

Following this line of thought, in this work, we extend the previously Quantum-Like Bayesian Network proposed by Moreira and Wichert (2016) by incorporating the framework of expected utility, this way presenting a graphical decision model called Quantum-Like Influence Diagram.

Generally speaking, an Influence diagram is a compact graphical representation of a decision scenario, which consists in three types of nodes: random variables (nodes) of a Bayesian Network, action nodes representing a decision that we need to make, and an utility function. The goal is to make a decision, which maximizes the expected utility function by taking into account probabilistic inferences performed on the Bayesian Network. However, since influence diagrams are based on classical Bayesian Networks, then they cannot cope with the paradoxical findings reported over the literature.

It is the focus of this work to study the implications of incorporating Quantum-Like Bayesian Networks in the context of influence graphs. By doing so, we are introducing quantum interference effects that can disturb the final probability outcomes of a set of actions and affect the final expected utility. We will study how one can use influence diagrams to explain the paradoxical findings of the prisoners dilemma game based on expected utilities. Moreover, since influence diagrams are widely used over the

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literature (for instance, in finance to determine the net present value of a project), we will also study the implications of using quantum probability inferences in such scenarios where violations of classical probability theory are not evident (or not present).

Acknowledgments This work was supported by national funds through Fundação para a Ciência e a Tecnologia (FCT) with reference UID/CEC/50021/2013 and through the PhD grant SFRH/BD/92391/2013. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

References


Social norms can be understood as the grammar of social interaction (Bicchieri 2006). As grammar in speech, it specifies what is acceptable in the given context. But what are the specific rules that direct human behavior? This paper presents two quantitative models of the self- and the other-perspective interaction based on the quantum model of decision-making (Busemeyer and Bruza 2014), that enable to define how the actor’s expectation about others influence his/her decision (and vice versa) in strategic games. Whereas two-dimensional model treats both perspectives as separate entities, four-dimensional model is based on their entanglement. Experimental results (Tesař forthcoming) show that a four-dimensional model is needed to explain variances in the data which point to mutual interconnectedness of both perspectives. In frame of the quantum model, we conclude that player’s concepts of the self and the other are entangled in strategic games.

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: through 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, but turns out to be 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? Current literature agrees, 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). 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

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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. 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 these are often violated.

Whereas there are a well-founded doubts about the validity of our classical rationality assumption, the known features of norm compliance can be easily explained in the quantum cognition framework (Tesař forthcoming). 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 goal in this paper is to compare two models (2D and 4D) that share basic assumptions of quantum modeling, nevertheless differ in one important aspect: whereas two-dimensional model treats both perspectives as separate entities, four-dimensional model Is based on their entanglement. Comparison of the models with known experimental results shows that all the main prediction of the general quantum model is met. Moreover, closer look to the double-stochasticity prediction, which is a distinguishing mark of 2D (separated) model, reveals some deviation from the data which supports the idea of that the perspectives are in fact entangled which corresponds to our qualitative social understanding of the problem.

References


2.6.5 The conjunction fallacy in quantum decision theory, Tatyana Kovalenko and Didier Sornette

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The conjunction fallacy is a renowned example of violation of classical probability laws, which is persistently observed among decision makers. Within Quantum decision theory (QDT), such deviations are the manifestation of interference between decision modes of a given prospect. We propose a novel QDT interpretation of the conjunction fallacy, which cures some inconsistencies of a previous treatment, and incorporates the latest developments of QDT, in particular the representation of a decision-maker’s state of mind with a statistical operator. Rather than focusing on the interference between choice options, our new interpretation identifies the origin of uncertainty and interference between decision modes to an entangled state of mind, whose structure determines the representation of prospects. On par with prospects, the state of mind can be a source of uncertainty and lead to interference effects, resulting in characteristic behavioral patterns.

We present the first in-depth QDT-based analysis of an empirical study (the touchstone experimental investigations of Shafir et al. (1990)), which enables a data-driven exploration of its underlying theoretical construct. We link typicality judgements to probability amplitudes of the decision modes in the state of mind, and quantify the level of uncertainty and the relative contributions of prospect’s interfering modes to their probability judgment. This enables inferences about the key QDT interference “attraction” $q$-factor with respect to different types of prospects - compatible versus incompatible.

We propose a novel empirically motivated “QDT indeterminacy (or uncertainty) principle,” as a fundamental limit of the precision with which certain sets of prospects can be simultaneously known (or assessed) by a decision maker, or elicited by an experimental procedure. For any type of prospects, we observe a general tendency for the $q$-factor to converge to the same negative range $q \in (-0.25, -0.15)$ in the presence of high uncertainty, which motivates the hypothesis of an universal “aversion” $q$. The “aversion” $q$ is independent of the (un-)attractiveness of a prospect under more certain conditions, which is the main difference with the previously considered “QDT quarter law”. The universal “aversion” $q$ substantiates the previously proposed QDT uncertainty aversion principle and clarifies its domain of application. The universal “aversion” $q$ provides a theoretical basis for modelling different risk attitudes, such as aversions to uncertainty, to risk or to losses.

2.7 Non-classical Probability Structures

2.7.1 Recovering non-Kolmogorovian probabilities within a contextual extension of Kolmogorov’s probability theory, Claudio Garola

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According to a standard view, quantum mechanics exhibits two relevant features. First, it is a contextual theory. Second, quantum probabilities do not satisfy Kolmogorov's axioms. We intend to show that these features can be connected within a formal scheme in which a Kolmogorovian probability is introduced on a universe of individual objects (or, more abstractly, on a set of possible worlds) together with a family of Kolmogorovian probabilities, each element of the family being defined on a subset of a set of contexts. In this framework quantum probabilities are interpreted as mean probabilities, which explains how they can be non-Kolmogorovian. Moreover, the distinction between compatible and incompatible physical properties arises in a natural way, and Kolmogorovian conditional probabilities coexist with quantum conditional probabilities because the two kinds of probabilities are seen as different theoretical notions. More generally, our formal scheme can be used to characterize a class of theories which contains as special cases classical mechanics, quantum mechanics and, possibly, some applications of the quantum formalism in cognitive sciences.

2.7.2 Topical Limits of Probability Spaces, Rostislav Matveev

In this joint work with J. Portegies we explore in a systematic way higher order relations between several random variables.

If a complex system (such as a living cell or a large neural network) is being observed via two or more measuring devices, their output may be considered as a pair or more of stochastic processes with the joint distribution. The question arises as to what long-term relations between such observations exist, beyond those measured by the linear combinations of entropy rates of the processes and their joint.

The systematic study of this question leads to the notion of tropical limit (as a "limit" of divergent sequence of objects viewed on a large-log-scale) arises. For example, entropy rate is an example of such a limit, when applied to a single stochastic process.

The entropy of a finite probability space $X$ measures the observable cardinality of large independent products $X^\otimes n$ of the probability space. If two probability spaces $X$ and $Y$ have the same entropy, there is an almost measure-preserving bijection between large parts of $X^\otimes n$ and $Y^\otimes n$. In this way, $X$ and $Y$ are asymptotically equivalent. It turns out to be challenging to generalize this notion of asymptotic equivalence to configurations of probability spaces, which are collections of probability spaces with measure-preserving maps between some of them. In this article we introduce the intrinsic Kolmogorov-Sinai distance on the space of configurations of probability spaces. Concentrating on the large-scale geometry we pass to the asymptotic Kolmogorov-Sinai distance. It induces an asymptotic equivalence relation on sequences of configurations of probability spaces. We will call the equivalence classes tropical probability spaces.
2.7.3 Majorization lattice and entanglement transformations, Gustavo Bosyk

Majorization lattice and entanglement transformations

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Majorization is nowadays a well-established and powerful mathematical tool with many and different applications in several disciplines as in economy, biology, physics among others. The spread applicability of majorization in the quantum realm emerges as a consequence of deep connections among majorization, partially ordered probability vectors, unitary matrices and the probabilistic structure of quantum mechanics. In this talk, we will review basics aspects of majorization focusing on the problem of interconversion of bipartite pure states applying local operation and classical communications (LOCC). More precisely, this problem consists in two parties, Alice and Bob, that share an (initial) entangled pure-state and their goal is to transform it in another entangled pure-state (target state), by applying LOCC. A celebrated result of Nielsen gives the necessary and sufficient condition that does this entanglement transformation process be possible \cite{1}. Indeed, this process can be achieved if and only if there exists majorization relation between the initial and target states. In general, this condition is not fulfilled, but one can look for an approximate target state. Vidal et. al have proposed a deterministic transformation using LOCC in order to obtain a state most approximate to target in terms of maximal fidelity between them \cite{2}. We present an alternative proposal by exploiting the fact that majorization is indeed a lattice for the set of probability vectors \cite{3}.

\textsuperscript{1} M.A. Nielsen, Phys. Rev. Lett. 83, 436 (1999)
2.8 Frontiers of Quantum Physics

2.8.1 On the emergence of the Coulomb forces, Jan Naudts

On the emergence of the Coulomb forces
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The possibility is investigated [1] that Coulomb forces are emergent forces. More precisely, the hypothesis is that Coulomb forces are carried by transversely polarized photons. Mathematical arguments in favor of the hypothesis are reported. Consequences of accepting the hypothesis are discussed.

The main argument is the existence of bound states of electrons and transversely polarized photons. The mathematical proof is given in the context of reducible quantum electrodynamics (QED). This formalism was introduced by Marek Czachor (see [2] and references given there) and underwent recently slight modifications and simplifications in order to make it mathematically rigorous [3–5]. The formalism deviates from standard QED by using reducible representations of the algebras of canonical commutation and anti-commutation relations. The wave vector of the fields is used as the reduction parameter.

In this formalism fields of electrons and photons are represented by wave functions in Fock space. It is shown that the energy of a free electron field can be reduced by entangling its wave function with that of a free photon. The resulting wave function describes a dressed electron field. The binding energy peaks in the long-wavelength limit. The claim is then that Coulomb forces originate from the interaction between dressed particles. Here the analogy is made with the polaron problem in Solid State Physics. Polarons result from the interaction of conduction electrons with lattice vibrations. They attract each other and, in some cases, even form bi-polaron states.

A further mathematical argument is the existence [5, 6] of a unitary transformation which removes the Coulomb forces from QED without modifying the time evolution of the charge distribution of the electron/positron field. This shows that a theory with and a theory without Coulomb forces are equivalent.

If Coulomb forces are indeed carried by transversely polarized photons then this has important consequences. Many of the mathematical problems in standard QED originate from the presence of longitudinal and scalar photons. In Solid State Physics the assumption is made that the charge of conduction electrons in metals is fully screened. This assumption can be replaced by the observation that long-wavelength photons do not propagate in metals and that therefore Coulomb forces are absent. In quantum chromodynamics the light cone gauge is used because then only transverse gluons remain [7]. Coulomb forces and gravity forces have their long-range character in common. Recently, E. Verlinde [8] claimed in a cosmological context that gravity is an emergent force. This suggests the statement that gravitational attraction is carried by transversely polarized gravitational waves, the existence of which has been established recently [9]. The importance of these consequences justifies further
investigations


2.8.2 On the lossless quantum coding with exponential penalization, Steeve Zozor

This talk is devoted to the lossless quantum data coding problem. To this end, we appeal to an encoding scheme that satisfies a quantum version of the Kraft-McMillan inequality. In the standard situation, studied for instance by Schumacher et al., Müller et al., Bostroem et al., or Hayashi, the goal is to minimize the arithmetic average length of the quantum codewords. Here, following the Campbells approach in the classical settings, we are interested in the minimization of an exponential type average, in order to penalize the large codeword lengths. We show that, similarly to the classical context, the exponential average length of the optimal code is related to the quantum Rényi entropy of the source, the von Neumann case being the particular case corresponding to the usual linear penalization. Moreover, using an exponential penalization, it also appears that the usual average length is then linked to both the Rényi and the von Neumann entropies.

2.8.3 Autonomous quantum clocks: how thermodynamics limits our ability to measure time, Paul Erker

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Time remains one of the least well understood concepts in physics, most notably in quantum mechanics. A central goal is to find the fundamental limits of measuring time. One of the main obstacles is the fact that time is not an observable and thus has to be measured indirectly. Here we explore these questions by introducing a model of time measurements that is complete and self-contained. Specifically, our autonomous quantum clock consists of a system out of equilibrium — a prerequisite for any system to function as a clock — powered by minimal resources, namely two thermal baths at different temperatures. Through a detailed analysis of this specific clock model, we find that the laws of thermodynamics dictate a trade-off between the amount of dissipated heat and the clock’s performance in terms of its accuracy and resolution. Our results furthermore imply that a fundamental entropy production is associated with the operation of any autonomous quantum clock, assuming that quantum machines cannot achieve perfect efficiency at finite power. More generally, autonomous clocks provide a natural framework for the exploration of fundamental questions about time in quantum theory and beyond.

2.9 Consciousness and Free Will
2.9.1 Transplanting “shut up and calculate” onto first-person inquiry, Urban Kordes

Transplanting »shut up and calculate« onto first-person inquiry

Urban Kordes

Since its conception, research on the mind has tried to model its research on natural science. It is interesting to note, however, that among the rare insights of natural science that never seem to find their way into the study of the mind are approaches developed in quantum physics. Even though mind research (especially the part interested in lived experience) and quantum physics share the problem of the inseparable interdependence of the observer and the observed.

Despite a plethora of attempts to connect the quirky world of quantum physics with the science of consciousness, proposals to link them on a methodological level are rare. This paper challenges the newly emerging field of first-person inquiry to consider just that: borrowing some of quantum mechanics’ methodological solutions – especially those concerning the attitude towards the pre-measurement existence of researched phenomena.

I believe that a methodological tutorial can lead to epistemological insights that could be interesting for the science of consciousness as well as physics itself. For example, reconsidering the process of gathering phenomenological data can lead to new insights regarding the question of what it means to measure.
2.9.2 Interface Theory of Perception and Conscious Realism, Chetan Prakash
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The Interface Theory of Perception of D. Hoffman says that perceptual experiences do not approximate properties of an objective world; instead, they provide a simplified, species-specific, user interface to the world. Conscious Realism states that the objective world consists of conscious agents and their experiences. Under these two theses, consciousness creates all objects and properties of the physical world: this reverses the mind-body problem.

In support of the interface theory I propose that our perceptions have evolved, not to report the truth, but to guide adaptive behaviors. This is done by proving a theorem in evolutionary game theory saying that perceptual strategies that see the truth will, under natural selection, be driven to extinction by perceptual strategies tuned instead to fitness.

I then give a mathematical definition of conscious agents, which, under the conscious realism thesis, leads to a non-dualistic, dynamical theory of conscious process in which both observer and observed have, mathematically, the same structure. The dynamics raises the possibility of emergence of combinations of conscious agents, in whose experiences those of the component agents are entangled.

In support of conscious realism, I discuss two more theorems showing that a conscious agent can consistently see geometric and probabilistic structures of space that are not necessarily in the world but are properties of the conscious agent itself. The world simply has to be amenable to such a construction on the part of the agent; and different agents may construct different (even incompatible!) structures as seeming to belong to this world. This again supports the idea that any true structure of the world is likely quite different from what we see. In particular, this suggests that space-time is a description, by human conscious agents, of location and dynamics on their perceptual interface, that the objects of Physics are icons on that interface and that phenomena as they appear to us are aspects of the dynamics of those icons on that interface.

What drives the emergence and evolution of particular species and their interfaces? Following F. Faggin I propose a mechanism for such emergence, suggesting that the drive is the desire of consciousness for comprehension, or self-knowing. What is required next is a theory of this process.
The essential structure of proposal, Free will Theorem (Conway and Kochen, 2006), that is expressed as Trilemma consisting of Free will, Locality and Determinism was also proposed by philosopher Michael Dummett (1964). The situation Dummett considers is the following. In some village, young men must succeed in Lion hunting to become social adults. It takes two days from the village to the hunting area, they hunt in two days, and finally it takes two days from the hunting area to the village. The chief in the village begins to dance for the success of lion hunting soon after the young men leave the village, and the dance continues six days. The last two days are redundant because the hunting was already done. Dummett asks how we reason the chief not to dance in the last two days. In the Free will theorem, quantum theory can give up Locality, and in Dummet’s paper the chief dancing for the success of Lion hunting which was already done also gives up Locality.

We here first show that the dancing chief can exist in a brain when the dancing chief and preceding Lion hunting are compared to intentional consciousness and unconsciousness including readiness potential respectively. Two axiomatic rules are here proposed, which defines how Locality, Determinism and Free will can determine the relationship among information processing in a brain. Since there are three combinations of refusal for trilemma (i.e., giving up either Locality, Free will or Determinism) three kinds of consciousness can be expressed from the trilemma. We show that the type I consciousness arisen from the combination in which Free will is given up can be compared to the consciousness of the people with Autism Spectrum Disorder (ASD), and that type II consciousness arisen from the combination in which Determinism is given up can be compared to the consciousness of the people with schizophrenia. Because of the axiomatic rules one can show that intentional
consciousness (Myself) is fused with other area relating to unconsciousness (Others in a brain) in type I consciousness and that Myself and Others in a brain are independently separated from each other in type II consciousness. In our terminology Self consists of Myself and Others in a brain. The axiomatic rules result in the asymmetric structure between the inside and outside of Self if Locality is not given up. Thus, in type I consciousness, in the inside of Self, Myself and Others in a brain are totally fused and in the outside of Self, Self is isolated from real others outside the body. It can explain impaired self-consciousness and bodily consciousness in the people with ASD. In type II consciousness, in the inside of Self, Myself and Others in a brain are separated from each other and in the outside of Self, Self is totally fused with real others outside the body. It can explain auditory hallucination, thought insertion and self-others integration found in the people with schizophrenia.

We show that the type III consciousness arisen from the combination in which Locality is given up can be compared to the consciousness of the healthy people. Through considering about type I and II consciousness, the significance of giving up Locality can be spelled out. Giving up locality implies neither fusion of parts nor separation of parts in Self. Giving up Locality implies that parts in Self (i.e. particular information processing in a brain) can be distinguished from each other on one hand and they can bring about one united collective Self on the other hand. Such complex behaviors can be compared to entanglement in quantum physics and we call it entangled state. In the healthy people, intentional consciousness claims its own voluntariness in motor action notwithstanding readiness potential underlies preceding motor command. In this sense, intentional consciousness is passively made to claim activeness. It can bring about sense of agency (SoA) and ownership (SoO) of bodily consciousness in intentional consciousness and co-existence of Determinism and Free will. Both SoA and SoO in the people with ASD and schizophrenia are impaired. It implies that neither fusion nor separation of different information processing cannot bring about SoA and SoO. Consciousness carrying Free will and Determinism cannot appear till different information processing are entangled. We refer to the model in which Bayesian and inverse Bayesian inference (Gunji et al., 2016, 2017) can implement the consciousness based on the trilemma.
2.10 Worldviews for Integration

2.10.1 Non-violent knowledge building. A proposal for academic writing, Federica Russo

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A chief philosophical question concerns the nature of knowledge. An accredited position sees knowledge as justified true belief, or JTB for short. In this position knowledge is representational, and the representations (our beliefs) of the world, to become *knowledge*, must be justified (in a sense to be further specified). This classic account has been challenged for a number of reasons, but in this talk I will rather focus on alternative solutions, notably those emphasising the *distributed* nature of cognition (distributed across several individuals as well as across material or social infrastructures) and those emphasising the *poietic* character of knowledge, viz. the fact that knowledge is *produced* (and is not a byproduct of our representations).

All this, I shall argue, becomes relevant for choosing argumentation strategies in writing our papers and books, and in teaching our students how to write a good academic piece. I shall make the point that strategies that favour or value winning arguments, negative results, or that fuel the counterexample factory should be replaced by writing strategies that instead foster collegial and collaborative attitudes, and that contribute to knowledge production, no matter how small the contribution might be. This, in a nutshell, is what I shall call non-violent knowledge building, inspired by the non-violent communication approach of Marshall Rosenberg.

2.10.2 Resisting Settler-Colonial Extractivism: Indigenous Women’s Alternative Epistemologies in Canada, Norah Bowman

In Canada, indigenous women are leading environmental activism protection of land and water from state-approved extractivism. In the course of this activism, these indigenous women present an alternative epistemology; their knowledge is validated by its origin in collective, historic, community storytelling. By doing so they not only challenge the state narrative of land and water, they present an alternative ontology inclusive of humans and non-humans. This ontology presents a powerful challenge to the materialist commodification of lands and rivers. Indigenous womens activism continues to function as a powerful unifying narrative in contemporary land and water protection in Canada, animating indigenous and non-indigenous activists and creating space for a rights-based discussion of rivers, mountains, and oceans. In my paper I will present examples of women fighting to protect watersheds threatened by mining and oil spills. I will share testimonies these women have presented to Canadian government and United Nations representatives, and I will show how their collective narrative epistemology presents a powerful challenge to the settler-colonial extractivism. From this model we can see the legalistic and academic effects of thinking about things - rivers and mountains - as conscious and living beings.
I take a critical stance towards the notion "worldview" as such. In our attempts at intercultural dialogue (with present and past), we way too easily assume that "everybody has a worldview", and so that worldviews are the thing that we all have in common, even if they are conflicting by content. Intercultural dialogue then can be realised by unearthing the basic common elements that shore up "all worldviews" and used as a kind of starting point. I reject this. We all do share a common fundamental experience of existing in this world, but that experience is not of a purely conceptual nature, nor does constitute a "worldview" in itself.

My point is that "world view" is already a very culture-determined way to describe people's interaction with the surrounding reality of which they are part, and that it is important to understand what silent preconditions are to be assumed before you even get into this mode of reality-interaction. The worldview-relation creates an externalised projection which is shaped and structured by a classical onto-logic which provides the ground for specific ontological possibilities, potentially at the dispense of other modes of interaction with the 'real world'. This ontological structure is what our philosophical tradition calls 'metaphysical' — a concept that is often misunderstood, as it is applied way too general to be of any analytical use.
2.10.4 Entanglement of ‘Art Coefficient’, or Creativity, Kyoko Nakamura

Entanglement of 'Art Coefficient', or Creativity

Kyoko Nakamura(1) & Yukio Pegio Gunji(2)

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Duchamp (1957) described subjective mechanism underlying creation of art. He called such a mechanism 'Art Coefficient'. The Art Coefficient can refer to the gap between the intention and realization of an artist, and outside (for example, interpretation of the viewer) entering the gap during that time. Traditionally, therefore, the significance of the Art Coefficient was considered inevitable discrepancy that it is required for a casual encounter between an artist and viewers. The work was interpreted by viewers independent of the artist’s intention. However, the Art Coefficient is the gap between what he/she planned and what he/she realizes in the creation of the arts, the gap can carry the significance as a trap to capture the outside composed positively. The intrinsic core of art is not artist’s intention but the gap between the intention and realization. The artist must design the Art Coefficient which cannot be intentionally controlled. That is nothing but entanglement of the inside and outside of the work.

While one of the authors, Nakamura, is a painter who draws Japanese paintings, the work of making a work is embedded just in the work. In the practice of work creation, universal questions about something at the meta level expanded to the outside is embedded. Thus, the entanglement of the inside and outside appeared when the viewer appreciates the work. Especially the entanglement can make “time” in which an interpreter can
live in viewing. It is aimed at solving the entanglement of artistic acts from Nabokov's short story "La Veneziana" and my own works. "La Veneziana" is a motif written as a portrait "A Young Roman Woman" (1512-1513) by the Venetian painter Sebastiano (Luciani), del Piombo (1485-1547). The flow of the talk is that the character goes into paintings and a lemon is handed over to the character from a basket held by a woman in the portrait. Nabokov implements entanglement of past, future and present, which bring about "time".

In many cases, time flows from the past to the future, the flow is assumed to be strict and irreversible. Also in Nabokov's novel, through the introduction, one can experience such "normal" time. But by the end of the day, paintings that should have been drawn in the past far · thus paintings depicting the far past · are counterfeit, that being revealed to be depicting the future, time suddenly Dynamic reverse runs from the future to the past. Therefore, the future and the past that never come and go will intersect. Changing the time Nabokov organized bore a gap in the story that should have been read, preventing the work to be realized in order. As a result, as a gap between the past and the preceding past that is related to the portrait, the difference between the different time sticking together, reality of the "real Maureen of Venice" emerges vividly in front of the reader. An emergent time of reality is created. Nabokov shows this just from a common lemon.

The creation of such time is by no means a monopoly of an artist. In everyday life, like Nabokov, we can find a chance of a small lemon and enjoy each living time. If you think that it is our birth from turning reality, it is crucial how you can make a difference there. In addition to our conclusion, we will also introduce Nakamura's works: "Platyplotus", Picture scroll of "Sawachi Dishes" and "Mirage of clams". "Platyplotus" has entangled on platypus, lotus. "Sawachi Dishes" entangled on party of eating traditional food “sawachi”. "Mirage of clams" entangled on mirage produced by clams.