Purdue Winer Memorial Lectures 2014

Contextuality From Physics to Psychology

Abstracts

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Contextual Semantics: From Quantum Mechanics to Logic, Databases, and Beyond

Samson Abramsky

We discuss quantum non-locality and contextuality, emphasising logical and structural aspects. We also show how the same mathematical structures arise in various areas of classical computation.
Contextual Emergence

Harald Atmanspacher

The concept of contextual emergence has been proposed as a non-reductive, yet well-defined relation between different levels of description of physical and other systems. I will illustrate it for the transition from statistical mechanics to thermodynamical properties such as temperature. Stability conditions are shown to be crucial for a rigorous implementation of contingent contexts that are required to understand temperature as an emergent property.

Are such stability conditions meaningful for situations beyond physics as well? As an affirmative example from cognitive neuroscience I will address the relation between neurobiological and mental levels of description. The crucial point here is the identification of a particular class of partitions of the neurobiological phase space, so-called generating partitions, which can be constructed from empirical data. They are coextensive with dynamically stable emergent mental states, which entails that mental and neural dynamics are compatible in the sense of topologically equivalence.
Leggett-Garg Inequalities, Pilot Waves, and Contextuality

Guido Bacciagaluppi

In this talk I first analyse Leggett and Garg’s argument to the effect that macroscopic realism contradicts quantum mechanics. After making explicit all the assumptions in Leggett and Garg’s reasoning, I argue against the plausibility of their auxiliary assumption of non-invasive measurability, using Bell’s construction of stochastic pilot-wave theories as a counterexample. Violations of the Leggett–Garg inequality thus do not provide a good argument against macrorealism. I then apply Dzhafarov and Kujala’s analysis of contextuality in the presence of signalling to the case of the Leggett–Garg inequalities, with rather surprising results. An analogy with pilot-wave theory again helps to clarify the situation.
Some Examples of Contextuality in Physics

Jose Acacio de Barros

In this talk we will examine three examples of contextuality in quantum mechanics: the two slit experiment, the Bell/EPR paradigm, and the Kochen-Specker theorem. We will argue that each of those examples bring different issues related to contextuality, and we will use them to discuss possible implications to psychology, in particular related to recent attempts to use the quantum mechanical formalism to model certain experimental results.
Block structured probability theory

Peter D. Bruza

E. Dzhafarov and J. Kujala have introduced the Contextuality-by-Default (C-b-D) approach, whereby each random variable is “automatically” labeled by all conditions under which it is recorded, and the random variables across a set of mutually exclusive conditions are probabilistically coupled. The aim of this presentation is to relate the C-b-D approach to block structured computer programming languages where variables are declared local to a syntactic construct called a “block”, but during compilation are labeled behind the scenes with respect to the block in which they are declared. In this way a variable declared in two blocks can have the same label but preserve two distinct identities. By means of examples, the notion of a probabilistic program, or “p-program”, will be introduced which is based on blocks. In p-programs not all random variables are globally accessible, which constitutes a key difference with standard probability theory. The semantics of p-programs will be illustrated using the well known relational database language SQL. The talk will attempt to address the question as to what degree constructs from relational database theory can successfully be used to operationalize a probability theory governed by C-b-D.
How Do We Decide Whether Questions Are Compatible or Incompatible in Psychology?

Jerome R. Busemeyer and Zheng Joyce Wang

Quantum probability theory has been successfully used to account for numerous puzzling findings in cognitive and decision sciences, including phenomena such as the conjunction fallacy, violations of rational decision theory, interference effects of categorization on decisions, asymmetric similarity judgments, order effects on causal reasoning, and others. Most of these accounts rely on the assumption that incompatible judgments are responsible for these effects. Critics argue that explanations based on incompatibility are post hoc, because we cannot determine whether questions are compatible or not before hand. In this talk, we define compatibility as applied to psychology, and we take steps towards identifying ways to determine in an a priori manner whether or not judgments are compatible. This we hope will provide ways to design stronger a priori tests of quantum models applied to psychology.
From Coupling to Copula: Examples from Modeling Multisensory Processes

Hans Colonius

Coupling means the joint construction of two or more random variables (or processes) usually in order to deduce properties of the individual variables or gain insight into distributional similarities or relations among them.’ [Thorisson, H. (2000) Coupling, stationarity, and regeneration, Springer-Verlag]. ‘Copulas are functions that join multivariate distribution functions to their one-dimensional margins.’ [Nelsen, R.B. (1999) An introduction to copulas, Springer-Verlag]. Both theories play an increasingly important role in probability and statistics. In this talk, I illustrate how some elementary concepts from both theories can be used to solve problems in developing and testing stochastic models of multisensory interaction, i.e., effects that occur when stimuli from more than a single sensory modality are to be processed by the perceiver.
End-Directedness and Context in Non-Living Dissipative Systems

James A. Dixon (with Bruce Kay and Dilip Kondepudi)

The extensive study of thermodynamically open, non-equilibrium systems in the context of self-organization has revealed that biological phenomena such as clocking, pattern formation, and chemotaxis may also be found more generally in non-living (e.g., chemical) systems. We show that another fundamental biological phenomenon, end-directedness, also appears in non-living systems. We present a non-living dissipative system that exhibits end-directed processes in seeking and drawing the energy needed to form and maintain its structure. The system can become sensitive to its context, defined as gradients other than its primary energy source, and use context to coordinate with its environment. Implications for biological systems will be discussed.
General Theory of Contextuality and Signaling in Probability Theory

Ehtibar Dzhafarov and Janne Kujala

We present a general definition of contextuality and signaling in abstract probabilistic terms. We discuss in detail how contextuality is measured “on top of signaling” in EPR/Bohm and Leggett-Garg type systems.
“It Is the Theory Which Decides What We Can Observe” (Einstein)

Thomas Filk

In particular in quantum physics, “measurements” are no longer considered as “passive acts of observation” but as an active interaction with the environment and a process which can (and in general will) have an influence onto the state of the measured system. Quantum contextuality, as it follows e.g. from the Kochen-Specker theorem, is just an extreme example of the extend to which the outcome of a measurement depends on the conditions and environmental influences acting on the observed system. I will give several examples from classical and quantum physics where the nature of the associated observables has an essential influence not only on what will be observed but also on what the reconstructed underlying ontology (as determined by the theory) is.
Two Ways of Borrowing from Physics

Emmanuel Haven

Why would an economist borrow concepts from physics? It is very reasonable to argue that the ultimate goal of applying concepts from a foreign discipline into one’s own discipline is precisely meant to augment one’s understanding of a thorny problem. Why bother otherwise?

In this talk we propose two very different ways of borrowing concepts from physics. The first way is the common route which is often travelled by inter-disciplinarians: use a methodology from physics and make it to ‘work’ in your own discipline. This can have very serious pitfalls. The second way, is more subtle, and consists of ‘importing’ a framework from physics but with the goal to unpick all the underpinnings which make that framework work in physics. As a result, one obtains a skeleton or a template which can function in a variety of unconnected disciplines. In this talk, we will give examples of those two ways of borrowing concepts from physics.
Foregrounding the Background: Cognitive Science as The Study of Self-Sustaining Embodiments of Context

Scott Jordan

Most contemporary cognitive scientists harbor a commitment to either direct- or indirect-realism. Common to both is a correspondence approach to reality and truth that asserts the following: (1) the important thing about reality is its independence of observers, and (2) science is a method that allows one to overcome subjectivity and, as a result, reveal reality’s observer-independent, ‘real,’ intrinsic properties. The present paper proposes that such a correspondence approach to truth and reality is ultimately insufficient. This is because defining reality in terms of observer-independence ultimately privileges human epistemology, and science, and detracts our attention from the more fundamental question of whether or not any phenomenon can exist in a context-independent fashion, as opposed to an observer independent fashion. Focusing on the notion of context independence opens the possibility of conceptualizing organisms as self-sustaining embodiments of context. Doing so, in turn, leads one to a coherence approach to reality and truth—the approach that was popular among idealist and continental philosophers. The present paper fleshes out the differences between coherence and correspondence driven approaches to reality and truth, propose an explanation of why cognitive science came to favor correspondence approaches, describes problems that have arisen in cognitive science because of its commitment to correspondence theorizing, and proposes an alternative framework (i.e., Wild Systems theory—WST) that is inspired by a coherence approach to reality and truth, yet is entirely consistent with science.
CHSH-inequality: Quantum Probabilities as Classical Conditional Probabilities

Andrei Khrennikov

The celebrating theorem of A. Fine implies that the CHSH inequality is violated if and only if the joint probability distribution for the quadruples of observables involved the EPR-Bohm-Bell experiment does not exist, i.e., it is impossible to use the classical probabilistic model (Kolmogorov, 1933). In this note we demonstrate that, in spite of Fine’s theorem, the results of observations in the EPR-Bohm-Bell experiment can be described in the classical probabilistic framework. However, the "quantum probabilities" have to be interpreted as conditional probabilities, where conditioning is with respect to fixed experimental settings. Our approach is based on the complete account of randomness involved in the experiment. The crucial point is that randomness of selections of experimental settings has to be taken into account. This approach can be applied to any complex experiment in which statistical data are collected for various (in general incompatible) experimental settings. Finally, we emphasize that our construction of the classical probability space for the EPR-Bohm-Bell experiment cannot be used to support the hidden variable approach to the quantum phenomena. The classical random parameter $\omega$ involved in our considerations cannot be identified with the hidden variable $\lambda$ which is used the Bell-type considerations.
Our (Represented) World: A Quantum-Like Object

Ariane Lambert-Mogiliansky (with François Dubois)

It has been suggested that observed cognitive limitations may be an expression of the quantum-like structure of the mind. In this paper we explore some implications of this hypothesis for learning i.e., for the construction of a representation of the world. For a quantum-like individual, there exists a multiplicity of mentally incompatible (Bohr complementary) but equally valid and complete representations (mental pictures) of the world. The process of learning i.e., of constructing a representation involves two kinds of operations on the mental picture. The acquisition of new data which is modelled as a preparation procedure and the processing of data which is modelled as an introspective measurement operation. This process is shown not converge to a single mental picture but can oscillate forever. We define a concept of entropy to capture relative intrinsic uncertainty. The analysis suggests a new perspective on learning. First, it implies that we must turn to double objectification as in Quantum Mechanics: the cognitive process is the primary object of learning. Second, it suggests that a representation of the world arises as the result of creative interplay between the mind and the environment. There is a degree of freedom that modifies the objective of rational learning.
The Logical Structure of Contextual Effects for Psychological Experimentation

Louis Narens

Recently, Hilbert space modeling from quantum mechanics has been introduced into cognitive psychology to model contextual effects and other perplexing psychological phenomena. In 1936 Birkhoff and von Neumann described the algebraic/logical structure inherent in Hilbert space modeling, and a modest generalization of this (i.e., orthomodular lattices) became the much studied area in mathematics, physics, and philosophy that is today called “quantum logic”, which is also a generalization of classical propositional logic. This talk derives a model of quantum logic from considerations about how experimenters reason across experiments in which the participants are put into different contexts. The derivation takes place in standard probability theory. The model is built out of counterfactual logic, and its propositions are equivalence classes of events that come from different possible worlds (experiments) and satisfy certain properties.
Review of Principles Attempting to Define Quantum Theory

Gary Oas

It is resoundingly clear that the physical world is best described by quantum theory. However, even with all its success, there is still no understanding of why this is so; there is currently no physical or informational principle that singles out quantum mechanics as the way that nature works. In this talk, various attempts to provide physical or informational principles to single out quantum mechanics are reviewed. Recent proposals constraining probability theory (exclusivity, local orthogonality) will be examined more closely from the perspective of negative (quasi-)probability.
Event, Context, and Probability in Philosophy, Psychology, and Quantum Theory

Arkady Plotnitsky

The paper offers, first, a brief discussion of the concept of context, the term often taken from granted or used uncritically, without a proper or even any definition. Then the paper considers how sufficient a context is in determining meaning (that of a statement, event, and so forth) in psychology and others social sciences, especially linguistics, on the one hand, and in physics, on the other. I argue in particular that, in contrast to classical physics (where measurement plays an auxiliary rather than shaping role), in quantum physics, specifically in the (low-energy) regimes governed by quantum mechanics, our decision concerning what kind of measurement we want to perform and, hence, the context of measurement play a constitutive role in determining the outcome of a given experiment. This form of contextuality is, in part, correlative to Bohr’s concept of complementarity. I shall argue, however, that the context of measurement can never fully determine a given event even in quantum physics. The reason for this is that this context itself could never be ever fully determined there, even though the degree to which it can be determined or at least demarcated in quantum physics is much greater than elsewhere, for example, in psychology or linguistics. Nevertheless, I argue that just as in psychology or linguistics, in quantum physics, too, while no meaning or event can be determined apart from a context, no context is ever fully sufficient for this determination because it is itself never completely determinable, in part for extra-physical, such as psychological and social, reasons. (Indeed, this is true even in classical physics, where the physical context of measurement can be neglected.) The determination by physical context, specially that of measurement (again, trivial in classical physics), is, however, sufficient for the effective disciplinary functioning of quantum theory, although quantum field theory introduces certain further complexities in this regard. I shall then consider, in closing, the degree to which this type of disciplinary determination by the context of measurement (or observation) is transferable to the use of quantum-like mathematical models in psychology—models that employ the mathematical formalism of quantum mechanics to describe and predict psychological processes.
A Quantum Approach to Context Effects in Human Similarity Judgments

Emmanuel Pothos (with James Yearsley, Albert Barque Durcan, Jennifer Trueblood, Jerome Busemeyer, and James Hampton)

Tversky’s (1977) well-known diagnosticity effect reveals that a similarity comparison between the same two stimuli can vary, depending on which other items are included in a set of relevant alternatives. Thus, Tversky showed that similarity judgments cannot be understood just in terms of pairwise comparisons, rather the relevant context needs be taken into consideration as well. Pothos, Busemeyer, and Trueblood (2013) presented a quantum model of similarity, which could accommodate Tversky’s (1977) diagnosticity finding (as well as some of his other main results). We discuss how contextuality arises in Pothos et al.’s (2013) model, the difficulty with alternatives approaches, and outline a proposal for extending the model. The extended quantum similarity model reveals that brittleness in the diagnosticity effect arises from competition with an attraction effect. As work in progress, we outline an experimental paradigm against which this novel prediction can be assessed.
Contextuality in Bohm & Hiley’s Ontological Interpretation of Quantum Theory

Paavo Pylkkänen

What is the ontology of the quantum theory? Traditionally, to ask for the ontology of a theory is to ask for the set of things whose existence is acknowledged by the theory (cf. Lowe (1995)). In classical physics, for example, the ontology was typically assumed to be the particles and the fields. As is well known, however, this question is notoriously difficult to answer in quantum theory. Niels Bohr famously implied that we should give up the attempt to formulate a quantum ontology. To empirically test any ontology we need to make use of phenomena. To empirically test a particle ontology we need phenomena where the position and momentum of the particle appear. Bohr emphasized that, say, the experimental conditions required to produce the phenomenon in which we measure the position are incompatible with those required to produce the phenomenon in which we measure the momentum. There is no single phenomenon in which both the position and the momentum of a quantum system can be accurately measured. Thus, implied Bohr, it is not legitimate to postulate an ontology in which a particle has simultaneously a well-defined position and momentum. So the issue for Bohr seems to be when it is legitimate to postulate an ontology in which a particle has simultaneously a well-defined position and momentum. So the issue for Bohr seems to be when it is legitimate to postulate an ontology.

Or, to put it differently, what does the incompatibility of phenomena associated with a single system imply for the ontology of that system? In the domain of classical physics it is possible to measure position and momentum with arbitrarily good accuracy within a single phenomenon, and thus one is allowed to postulate a particle ontology, in other words to make the transition from phenomena to ontology. Usually in classical physics one just talks about the particle and its properties, ignoring the phenomenon in which these were measured. However, according to Bohr in quantum theory we are not allowed to “slip into” a quantum ontology from quantum phenomena in a similar way, because the latter are incompatible. If Bohr is correct, quantum theory indeed teaches us an epistemic lesson. We are not able to use an explanatory strategy that has worked so well in many other instances in science, i.e. the strategy of postulating an underlying ontology to explain observed phenomena. But perhaps it is possible to go beyond Bohr? This was certainly attempted by David Bohm who in 1952 proposed a quantum ontology (similar to de Broglie’s 1926), and further developed this with Basil Hiley and their research students (Bohm & Hiley 1993). In this talk I will describe and evaluate Bohm & Hiley’s interpretation. In what sense does it provide us a quantum ontology? How does the contextuality characteristic of quantum phenomena reflect itself in this interpretation? Might this kind contextuality also be useful when describing cognitive, psychological phenomena?


Symmetry and the Behavioral Order of Joint-Action and Social Coordination

Michael J. Richardson

A fundamental feature of social behavior is face-to-face or co-present physical interaction. The success of such joint-action (including joint-musical performance), whether measured in terms of social connection, goal achievement, or the ability of individuals to understand and predict the meaningful intentions and behaviors of others, is not only dependent on numerous neural-cognitive processes, but also on the physical and informational processes of perceptual-motor coordination. Understanding and modeling the dynamics of these coordination processes, including how they emerge and are maintained over time, as well as how differing stable states of coordination are activated, dissolved, and transformed is therefore imperative. Here, I will discuss previous research aimed at identifying behavioral dynamics of interpersonal and multi-agent perceptual-motor coordination and how symmetry and symmetry-breaking principles operate to constrain and shape the self-organized order of such behavior, including complementary joint-action behavior. In turn, I will argue that the behavioral dynamics of perceptual-motor coordination not only lawfully express the physical, informational, and neural-cognitive relations that underlie successful joint-action, but also operate to enslave the behavioral intentions, action strategies, and cognitive processes of socially situated co-acting individuals.
Context Effects Due to Question Order Explained by Quantum Probability

Richard Shiffrin (with Jerome Busemeyer and Zheng Joyce Wang)

Context effects are omnipresent in human behavior, and are the result of many and varied causes. In a recent PNAS publication (Wang et al., 2014) we examined the different results that obtain when two yes-no questions are asked back to back in different orders (for two different groups of respondents). An analysis of all national surveys (mostly by Pew and Gallup) in a recent 10 year window that carried out this manipulation showed a surprising context result, termed the QQ equality: Across the two question orders, the change in the probability of saying yes twice plus the change in the probability of saying no twice was always close to zero, including the many cases in which there existed strong order effects. The analysis that revealed this effect was carried out solely because the result was predicted (in a universal and parameter free fashion) by a quantum probability model of human decision making and question answering developed by Busemeyer and Wang. We have not been able to find a simple and coherent explanation of this finding using any traditional form of cognitive modeling. This finding suggests that human cognition is at least in part characterized by quantum probability, and that this factor is an important component of context effects.
A Quantum Bayes Net Approach to Causal Reasoning

Jennifer S. Trueblood (with Percy Mistry and Emmanuel M. Pothos)

When individuals have little knowledge about a causal system and must make causal inferences based on vague and imperfect information, their judgments often deviate from the normative prescription of classical probability. Previously, many researchers have dealt with violations of normative rules by elaborating causal Bayesian networks through the inclusion of hidden variables. While these models often provide good accounts of data, the addition of hidden variables is often post hoc, included when a Bayes net fails to capture data. Further, Bayes nets with multiple hidden variables are often difficult to test. Rather than elaborating a Bayes net with hidden variables, we generalize the probabilistic rules of these models. The basic idea is that any classic Bayes net can be generalized to a quantum Bayes net by replacing the probabilities in the classic model with probability amplitudes in the quantum model. We illustrate our approach with new experiments and model comparisons. We also discuss several model predictions, which we confirm experimentally.