

## Founding Editors

Gerhard Goos

*Karlsruhe Institute of Technology, Karlsruhe, Germany*

Juris Hartmanis

*Cornell University, Ithaca, NY, USA*

## Editorial Board Members

Elisa Bertino

*Purdue University, West Lafayette, IN, USA*

Wen Gao

*Peking University, Beijing, China*

Bernhard Steffen

*TU Dortmund University, Dortmund, Germany*

Gerhard Woeginger 

*RWTH Aachen, Aachen, Germany*

Moti Yung

*Columbia University, New York, NY, USA*

More information about this series at <http://www.springer.com/series/7407>

Bob Coecke · Ariane Lambert-Mogiliansky (Eds.)

# Quantum Interaction


11th International Conference, QI 2018

Nice, France, September 3–5, 2018

Revised Selected Papers

*Editors*

Bob Coecke   
University of Oxford  
Oxford, UK

Ariane Lambert-Mogiliansky   
Paris School of Economics  
Paris, France

ISSN 0302-9743                      ISSN 1611-3349 (electronic)  
Lecture Notes in Computer Science  
ISBN 978-3-030-35894-5              ISBN 978-3-030-35895-2 (eBook)  
<https://doi.org/10.1007/978-3-030-35895-2>

LNCS Sublibrary: SL1 – Theoretical Computer Science and General Issues

© Springer Nature Switzerland AG 2019

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Preface

Quantum Interaction (QI) is an emerging interdisciplinary field of science. It proposes applications of quantum theory to a large variety of domains from psychology, economics, semantic and memory, natural language processing, cognition, information retrieval, biology, and political science. The applications addressed typically operate at a macroscopic scale and could not be considered quantum in a quantum mechanical sense. However, they share key properties with quantum systems. These include non-commutativity of measurement, indeterminacy, non-separability, contextuality, and harmonic oscillations. QI thus refers to the use of the quantum mathematical, conceptual, or probabilistic structures outside of physics. Since its inception in 2007, QI has evolved from nearly exclusively theoretical and conceptual contributions to more applied works including lab experiments.

QI 2018, the 11th International Conference on Quantum Interactions was part of a series of international conferences. This now traditional conference started in 2007 as part of the Association for the Advancement of Artificial Intelligence (AAAI) Spring Symposia at Stanford University. For the second time the conference was held in France (QI 2012 was in Paris). The 11th conference took place during September 3–5, 2018, in Nice. It was hosted by Nice Graduate School of Management at the Sophia Antipolis University.

In this year's conference we had many distinguished speakers, and we are happy to have contributions to this volume from two of our keynote speakers. Prof. Michel Bitbol, Directeur de recherche CNRS at Ecole Normale Supérieure, Paris, France, offers a philosophical and historical perspective that unveils deep reasons for a quantum approach in human sciences. Prof. B. P. F. Jacobs, from the Institute for Computing and Information Sciences (ICIS), Correctness Digital Security Group at Radboud University Nijmegen, The Netherlands, provides a review of the questions related to updating in the classical and quantum context and introduces challenging research issues related to probabilistic logic.

The conference had an affiliated workshop entitled Workshop on Compositional Approaches in Physics, NLP, and Social Sciences (CAPNS 2018). Its proceedings appeared in ENTCS.

We would like to take the opportunity to thank everybody who made this symposium possible: the Steering Committee, the Program Committee members for their reviewing job, the proceedings and the publicity chairs, those responsible for the website design and management, and all the conference participants and presenters. We are grateful for the support given by the University of Nice Sophia Antipolis.

June 2019

Bob Coecke  
Ariane Lambert-Mogiliansky

# Organization

## Program Chairs

Bob Coecke	University of Oxford, UK
Ariane	Paris School of Economics, France
Lambert-Mogiliansky	

## Steering Committee

Peter Bruza	Queensland University of Technology, Australia
Trevor Cohen	University of Texas at Houston, USA
Bob Coecke	University of Oxford, UK
Ariane	Paris School of Economics, France
Lambert-Mogiliansky	
Dominic Widdows	Grab Technologies Inc., USA

## Program Committee

Irina Basieva	LNU, Sweden
Bob Coecke	University of Oxford, UK
Trevor Cohen	University of Texas, Houston, USA
Ehtibar Dzhafarov	Purdue University, USA
Bart Jacobs	Radboud University, The Netherlands
Chris Heunen	The University of Edinburgh, UK
Dominic Horsman	University of Durham, UK
Dimitri Kartsaklis	Apple Inc., UK
Kirsty Kitto	University of Technology, Sydney
Andrei Khrennikov	Linnaeus University, Sweden
Ariane	Paris School of Economics, France
Lambert-Mogiliansky	
Bill Lawless	Paine College, USA
Martha Lewis	University of Amsterdam, The Netherlands
Dan Marsden	University of Oxford, UK
Simon Perdrix	CNRS, University of Grenoble, France
Emmanuel Pothos	City University London, UK
Quanlong Wang	University of Oxford, UK

## Local Committee

Sébastien Duchêne	University of Nice Sophia Antipolis, France
Ismaël Rafai	University of Nice Sophia Antipolis, France
Laurence Gervasoni	University of Nice Sophia Antipolis, France

# Contents

## Fundamentals

Why Should We Use Quantum Theory? The Case of Human Sciences . . . . .	3
<i>Michel Bitbol</i>	

## Quantum Cognition

The Power of Distraction: An Experimental Test of Quantum Persuasion. . . .	25
<i>Ariane Lambert-Mogiliansky, Adrian Calmettes, and Hervé Gonay</i>	
Are Decisions of Image Trustworthiness Contextual? A Pilot Study . . . . .	39
<i>Peter D. Bruza and Lauren Fell</i>	
Probabilistic Programs for Investigating Contextuality in Human Information Processing . . . . .	51
<i>Peter D. Bruza and Peter Wittek</i>	
Episodic Source Memory over Distribution by Quantum-Like Dynamics – A Model Exploration . . . . .	63
<i>J. B. Broekaert and J. R. Busemeyer</i>	

## Decision-Making

Balanced Quantum-Like Model for Decision Making. . . . .	79
<i>Andreas Wichert and Catarina Moreira</i>	
Introducing Quantum-Like Influence Diagrams for Violations of the Sure Thing Principle . . . . .	91
<i>Catarina Moreira and Andreas Wichert</i>	

## Cybernetics and AI

Fuzzy Logic Behavior of Quantum-Controlled Braitenberg Vehicle Agents . . . . .	111
<i>Rebeca Araripe Furtado Cunha, Naman Sharma, Zeno Toffano, and François Dubois</i>	
Moral Dilemmas for Artificial Intelligence: A Position Paper on an Application of Compositional Quantum Cognition . . . . .	123
<i>Camilo M. Signorelli and Xerxes D. Arsiwalla</i>	

**Probability and Beyond**

Density Hypercubes, Higher Order Interference and Hyper-decoherence:  
A Categorical Approach. . . . . 141  
*Stefano Gogioso and Carlo Maria Scandolo*

**Information Retrieval**

Investigating Non-classical Correlations Between Decision  
Fused Multi-modal Documents . . . . . 163  
*Dimitris Gkoumas, Sagar Uprety, and Dawei Song*

Investigating Bell Inequalities for Multidimensional Relevance  
Judgments in Information Retrieval . . . . . 177  
*Sagar Uprety, Dimitris Gkoumas, and Dawei Song*

**Short Paper**

An Update on Updating. . . . . 191  
*Bart Jacobs*

**Author Index** . . . . . 193