

Princeton-Humboldt Cooperation and Collective Cognition Network (CoCCoN)

Abstract

The interdisciplinary network will provide a unique collaborative research environment for exploring cooperation and collective cognition in human and animal systems. The proposal will explore two interrelated research threads: (1) the impact of variable environments on evolution and persistence of cooperation and (2) fundamental dynamics of behavioral contagion and its role in collective cognition. Specific attention will be paid to applications of the research towards promoting sustainability in coupled socio-economic-environmental systems and understanding collective risk perception. A core part of the network activity will be (1) two interdisciplinary workshops, and (2) a research-based CoCCoN-Q-Course for senior undergraduates and young graduate students (Master & 1st year PhD level). It will provide a unique setting for students to gather early experience in international collaboration while working on self-determined projects. A special methodological focus of the network will be novel visualization methods for presentation and analysis of complex network data. The network idea is founded in previous fruitful individual research contacts, both between and within universities, but goes well beyond these existing individual links by forming a wide interdisciplinary network with new links around a specific, common research topic.

Objectives

With the proposed activity we aim (1) to establish a highly visible, interdisciplinary network on “Cooperation & Collective Cognition” between the Princeton University (PU) and Humboldt Universität zu Berlin (HU), (2) to bridge disciplinary barriers by bringing together empiricists and theoreticians from different backgrounds such as biology, physics, social sciences, economics, psychology & engineering, in order to develop and pursue highly innovative, cross-disciplinary research on cooperation and collective cognition, (3) to integrate an international, interdisciplinary research-based training program for students, and to (4) to improve the research and teaching portfolio by exploring innovative visualization techniques and developing novel electronic learning materials on complex systems, data analysis on collective behavior for students in quantitative biology, ecology, psychology, sociology and economics.

Motivation & State of the Art

Collective behavior of interacting agents in biological, artificial and socio-economic systems may often reveal unexpected large scale dynamics and patterns, which cannot be easily anticipated from the microscopic rules governing the interactions of individuals. In many cases the corresponding mathematical models, aimed at capturing the essential dynamics of these very different systems, have a common foundation originating from the research on complex systems and self-organization in theoretical physics and applied mathematics. However despite this common ground, differences in experimental methods and primary research questions, often lead to a divergence of the research effort and impose significant barriers for interdisciplinary exchange. Nevertheless, over the past decades we have seen many examples of scientific cross-fertilization where ideas from one discipline became highly influential in other disciplines and

sometimes lead to emergence of new important fields of research. Prominent examples include the formulation of evolutionary game theory based on initial groundbreaking research on economic game theory, or the generalization of swarm intelligence dynamics from biology to computer science and into the social and economic sciences.

The main goal of the proposed activity is to bring together scientists from both institutions interested in the common theme of “*Cooperation & Collective Cognition*” from very different disciplinary angles, to promote stronger integration of faculty between both institutions but also between departments of each individual university. Furthermore, it will give selected students from both universities the opportunity to widen their scientific scope, strengthen their scientific independence and gain first-hand experience in cross-disciplinary, international collaborative research. The general field of research of the envisioned interdisciplinary network will be cooperation and collective cognition of groups in socio-economic and ecological systems. Here we want to focus on the following main questions: (1) What are the differential roles of extrinsic and intrinsic factors on the evolution and persistence of cooperation? (e.g. spatio-temporal resource distribution versus interaction topology) (2) How does complex contagion shape collective behavior in animal groups and large-scale dynamics of socio-economic systems? An important aim of the network research will be to move beyond fundamental research questions towards real-world applications. A specific applied focus in the context of human systems, will be the question how sustainable behavior can be promoted and maintained. Here the evolution of appropriate norms play a fundamental role in shaping how humanity can deal with environmental challenges and policy making (Kinzig et al. 2013), creating a common ground surrounding core topic of psychology, economics and coupled social-ecological systems.

Evolution of Cooperation: Role of Complex Environment and Social Norms

The question of evolution and persistence of cooperation of selfish agents has been a major field of research in biology and economics for decades, with developments in evolutionary game theory have been highly instrumental for the study of conditions for the emergence of altruistic behavior. Classical biological theories of cooperation include kinship theory (Hamilton, 1964) and reciprocal altruism (Trivers, 1971). A lot of studies focused on different variants of so-called evolutionary games, with the Prisoner's Dilemma game being the most known one (Axelrod, 1997; Nowak, 2006; Tarnita et al, 2011). In 2006, Nowak described five mechanisms for emergence of cooperation: kin selection, direct reciprocity, indirect reciprocity, network reciprocity and group selection and discussed general conditions under which natural selection can lead to cooperation. Another important research topic in economics and social sciences is cooperation in public good usage and the corresponding free rider problem (Levin, 2014, Ostrom 2015). This type of problems are particularly relevant to current global challenges in terms of sustainable management of resources and environmental protection (Kinzig et al 2013). Here, different mechanism have been discussed which may sustain cooperation such as social norms and sanctions (Fehr & Fischbacher, 2004; Kinzig et al 2013).

Despite advances in the field, many questions remain unanswered. For example, a fundamental question relates to the ‘optimality’ or ‘rationality’ assumption underlying game theoretic approaches. Here, an often neglected, important distinction is the one between ultimate and proximate causation. Game theory typically assesses behavioral strategies based on utility functions, which are often meant to operationalize ultimate causation. However, observed behaviors may emerge as a consequence of proximate mechanism, which might have been adaptive in a completely different evolutionary context and may be maladaptive due to changes in the environment or nature of social interactions (Capra & Rubin, 2011). Classic examples of such possibly maladaptive proximate psychological mechanisms are cognitive biases intensely studied in behavioral economics (Camerer et al, 2004; Kahnemann, 2006).

Another ongoing field of research is the emergence of social structure (e.g. clubs, coalitions), which may favor cooperation. For example, it was shown recently how small agreements and formation of clubs may promote sustained cooperations in the context of climate change (Hannam et al, 2015). In a recent model of coalition formation on adaptive networks (Auer et al, 2016), the network influence leads to complex dynamics not observed in game-theoretic coalition formation models (such as Heitzig, 2012) or in pure network models such as the adaptive voter model (Holme & Newman, 2006). In particular, the coalition size distribution often displayed two distinct classes of coalitions: a few competing macroscopic coalitions of similar size and a bulk of much smaller “mesoscopic” ones of various sizes. However, the macroscopic coalitions emerge only for subcritical rates of network adaptation, confirming the risk that social ties' getting ever more flexible may lead to fragmentation of society.

A major focus of the network shall be to review and explore the impact of the spatio-temporal dynamics of extrinsic factors (e.g. resource distribution and availability) on the evolution and persistence of cooperation, and how it differs from intrinsic factors characterizing the system (e.g. structure of social interactions, cliques, etc.) (Santos et al, 2006). In particular, we plan to address the question of how social norms may emerge at the group level (Santos et al, 2016). Here, social norms can be viewed as proximate mechanisms towards an ultimate goal (e.g. maximization of benefits, punishment of defectors). They may have highly adaptive value in the context of a given combination of extrinsic and intrinsic factors, but are likely to introduce a high degree of inertia in collective behavior, which may become disadvantageous for sudden changes of the environment. We will bring a new highly interdisciplinary perspective by comparing empirical observations of social norms in human groups to (proto-)social norms in animals populations, as observed in closely related ungulate populations, which may exhibit very different social structures (Sundaresan et al, 2006). Here, a major challenge is the development of mathematical models of collective behavior and social norms (Ehrlich & Levin, 2005; Levin, 2009), which on the one hand provide a sufficiently general framework for fundamental investigation of the interplay of extrinsic and intrinsic factors, and on the other hand can be connected with actual empirical data on the various ecological and social system, and more importantly can make testable predictions.

Behavioral Contagion and Collective Cognition

Contagion processes within social and economic networks are an active area of research, which received a lot of attention with the rise of the internet, social media, and the globalization of economic and social relationships. In a seminal work, Granovetter (1973) suggested that weak, but long-reaching links are particularly important for diffusion of information in social networks (“strength of weak ties”), and since then a lot of researchers studied contagion processes in social networks (see e.g. Valente, 1996, Kempe et al 2003). Recent findings suggest that spreading of ideas, trends or innovation proceeds via so-called complex contagion, which differs fundamentally from simple contagion processes encountered in disease spreading or information spreading (Centola and Macy 2007): In simple contagion, the probability to get 'infected' can be decomposed into a superposition of independent binary contact processes and corresponding probabilities (as in real disease spreading). For complex contagion such a decomposition is not possible - whether an agent becomes 'infected' depends in a complex way on the local network structure. Following questions become important: How many of its neighbors are infected at a given time? What is the fraction of the total neighborhood? What is the temporal coincidence? From theoretical point of view, there is a fundamental difference between simple and complex contagion processes (Dodds & Watts, 2004).

Centola and Macy (2007) have pointed out that complex contagion may actually negate the “strength of weak ties” promoted by Granovetter. Complex contagions in social dynamics continues to be a vibrant

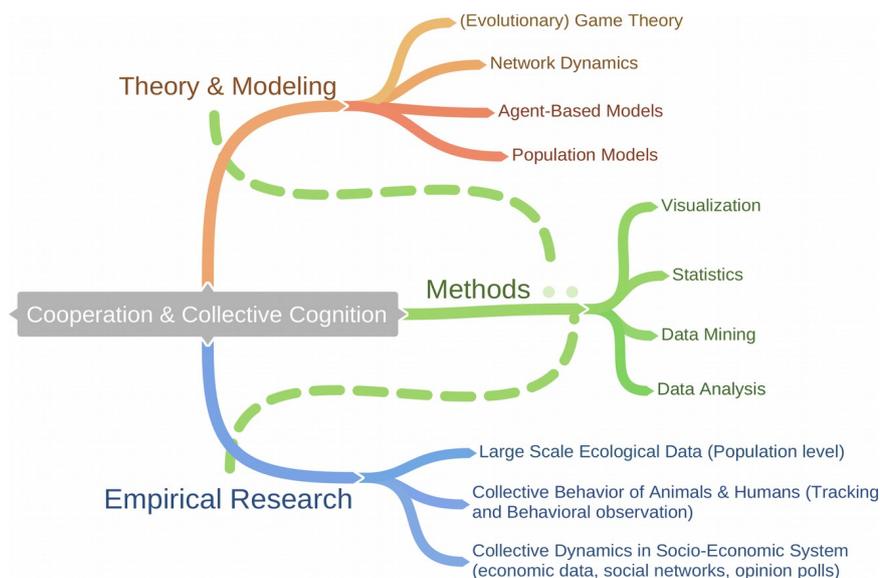


Illustration 1: Bridging the gap between empirical and theoretical research: Schematic visualization of the methodological variety within the CoCCo-Network.

research field up to date. In particular the rise of the Internet and social media has opened immense research opportunities and access to new forms and large amounts of data, which on the one hand allows to characterize in detail complex contagion phenomena, and on the other hand enables hypothesis testing and theory predictions with large data sets. Some recent research examples on complex social contagion are spreading of online innovations (Karsai, 2014) and information diffusion and trends in social media (Hodas & Lerman, 2014).

A possibly important application field of complex contagion is the assessment of risks in economic context (see e.g. Cont et al 2010). For example, risk perception has been almost studied exclusively as individual cognitive mechanisms in which individuals collect, process, and form perceptions effectively disconnected from the social system (Scherer and Cho 2003). In reality, behavioral responses are intimately linked to the way information is acquired in the social environment, something that has been largely neglected in the literature so far. Here one can also establish an interesting connection to the other main topic of cooperation, if one considers the contagion of behavior through social networks, e.g. spread of cooperative/sustainable behavior in a network (Suri and Watts, 2011).

On the other hand, in biology and ecology new digital tracking technologies allow the study of complex behavioral contagion processes in large animals groups (e.g. alarm waves) (Herbert-Read, 2015, Rosenthal, 2015), as well as the detailed characterization of animal social networks. Very recently, Rosenthal et al (2015) have analyzed in detail startling response in fish schools and have shown that the spreading of the behavioral response is driven by a complex contagion process. This new observations of animal groups raise some important fundamental questions about the adaptive value of complex contagion in an evolutionary context of living in groups and collective information processing. Here, individual risk perception plays an important role in the occurrence and spread of alarm responses through the group (Krause, 1993a,b; Rosenthal 2015), which in turn establishes an interesting analogy to the risk contagion problems of high relevance in human financial systems.

Despite these analogies between behavioral contagion processes in animal and modern human systems, there

remain many open questions. In particular, it is very likely that the higher cognitive capacity of humans fosters strategic behavior to a greater degree than seen in animal populations. The distinction between simple and complex contagion is rooted in theory of complex systems. However, in psychology it appears more natural to distinguish between contagions involving “imitations” and those involving deeper cognitive processes such as “information, “ beliefs,” and “ideas”. Discussing similarities and differences of contagion in human and animal systems, as well as, the different classifications across disciplines will provide important insights into the specific dynamics and possible trade-offs of behavioral contagion. It is possible that the complex nature of the social contagion in humans may be strongly context dependent; it may have offered adaptive advantages during the human evolutionary history in a social environment, which was drastically different from the modern one. Thus connecting the evolutionary perspective with socio-economic research will provide important insights into possible pathological behavior of behavioral contagion in humans in our modern, rapidly evolving social environment.

Furthermore, the vast majority of studies on complex contagion focuses on specific systems and the dynamics of the contagion process is studied in this particular context, and a systematic exploration of the properties of the complex contagion processes is limited either to very simple computational models (Dobbs & Watts, 2002). To our knowledge no systematic comparison of simple and complex contagion dynamics has been undertaken so far. But there are ongoing and planned projects on contagion processes involving members of the network, in the context of animal groups (Brockmann, Krause, Romanczuk) and in socio-economic systems (Coman, Cabrera, Chen). Here CoCCoN will offer a unique opportunity to integrate these different approaches, and provide a larger perspective with added benefits to all participants.

Bridging the gap between empirical and theoretical research

An important challenge which applies to both research topics discussed above, is how to realize a fruitful bi-directional exchange between empiricists and theoreticians to enable excellent research with high impact far beyond specific scientific niches. Our planned network brings together scientists with very different methodological backgrounds both in experiment and theory: On the one hand we have experts in mathematical modeling techniques ranging from spatially explicit agent-based and qualitative socio-ecological models (see e.g. Eisenack et al, 2006; Romanczuk et al 2012; Leonard, 2014), game theory (Fey & Ramsay, 2010; Tarnita et al 2009, Levin, 2009), to complex networks and coarse-grained population level approaches (see e.g. Arenas et al, 2008; Brockmann & Helbing, 2013; Kevrekidis et al 2003;). On the other hand, the represented empirical methods range from qualitative system level analysis (see e.g. Arlinghaus et al, 2007; Hanisch et al, 2013), via sociological surveys and psychological experiments (see e.g. Coman & Hirst, 2012; Salganik & Heckathorn, 2004; Shepherd & Levy Paluck, 2014), economic data (Chen, 2014; Härdle & Cabrera, 2012), to high-resolution spatio-temporal tracking data of individuals both in realistic field conditions as well as laboratory settings (Krause et al, 2013; Rubenstein, 2015). Thus a core motivation of the proposed center is to facilitate discussions across disciplinary and methodological divide: The aim is to sensitize theoreticians to restrictions of the various empirical methods in the context of studying cooperation and collective cognition: What can be measured? What theoretical predictions can be tested? What are the uncertainties? On the other hand the discussion will familiarize the participating empiricist with fundamental problems and trade-offs encountered in modeling and mathematical description of complex systems: From ‘minimal’ models of self-organized collective behavior to highly-detailed models parameterized by data focusing dynamics of specific systems.

Here, we want to emphasize the mediating role between theory and experiments of complex data processing methods, like advanced statistics, data mining and visualization. Within this particular network activity we

plan to put a special focus on data visualization, and in particular on visualization of complex networks in social and economic context. Here, we will explore how (interactive) visualization techniques can be used not only for data presentation, but as actual visual research tools both for empirical and theoretical scientists. For this purpose, we will invite local experts on visualization to participate in selected network activities.

Project Work Plan & Network Structure

The two core activities of CoCCoN will be the facilitation of cross-institutional and interdisciplinary connections via (1) the development of collaborative research projects, and (2) the integration of a training course centered around independent research-based learning in small international and interdisciplinary student teams. Due to the large physical distance we will rely heavily on web conferencing and computer-mediated collaboration tools.

Research Exchange and CoCCoN Postdoctoral Fellow(s)

The research exchange and collaboration will be realized via three different integrated activities: (1) common workshops, (2) E-seminars connecting the Princeton and Humboldt groups using web conference tools and (3) individual visits within topical sub-groups.

Two large, one week workshops shall frame the collaborative research within the network: one in Princeton towards the beginning of the activity (March/April 2017), and a second one approximately 12 months later, in early 2018. The time before the first workshop (Fall 2016) will be used for general coordination, initial scientific exchange, and selection of students and fellows. Here, in particular a first virtual meeting shall take place. This meeting will connect groups from both institutions using online conferencing tools, and will give each PI/group the opportunity to briefly present their past and present research relevant to the topic of the network in brief electronic presentations (<5 slides, <5mins). This first virtual meeting would be used to identify common interests and inspire first individual contacts between groups in Princeton and Humboldt at various levels (PIs, PostDocs, PhDs). This initial scientific “get-to-know-each-other” will save precious face-to-face time during the following first workshop, for in-depth presentation and discussion of research as well as development and pursuit of collaborative research within the network.

The first workshop will take place in Princeton. Its primary purpose is the discussion of common research interests and development and consolidation of corresponding collaborative research plans. Here in particular, smaller sub-teams will be formed, which will focus on specific research questions. The second workshop towards the end of the activity will take place at HU and will offer the possibility to present and discuss research initiated within the network, discuss further activities beyond the duration of the specific funding, and give students within the integrated graduate training group (CoCCoN-Q-Course) the opportunity to present their projects. Finally this workshop will be used to initiate a common publication, which will be either a special journal issue or an edited monograph on the topic of the network, with articles/chapters being contributed by the network participants.

In between the two workshops a regular, monthly electronic seminar shall take place. This seminar will give representatives of each participating group the possibility to present in an informal setting their ongoing research, and to discuss it with the entire network. During a single seminar 20-30min presentations shall be given one by the Princeton and one by the Humboldt side. Finally, the research and exchange within the sub-groups shall be facilitated small-scale visits within the sub-teams formulated during the first workshop.

Previous experience in similar interdisciplinary and international collaborations, such as within the “Center for Reality Mining of Animal-Human Systems”, have shown how essential it is to have individual junior scientists fully dedicated to the research of the initiative. Therefore an important component will be the

distinguished CoCCoN-Postdoctoral Fellow. The fellow position financed by the network is inspired by the P.R.I.M.E. fellowship introduced recently by the DAAD: the fellow will spend 9 months in Princeton and 9 months in Berlin, while pursuing independent research within the scope of the network. The candidates for the fellowship are expected to have a strong background in either quantitative data analysis and/or modeling of complex systems. The fellow shall in particular work at a core issue that often hampers interdisciplinary cooperation by testing the applicability of theoretical models to empirical data present in our network. A core aspect of the Q-Course concept promoted by bologna.labs is the supervision of the course by junior researcher(s) (PhDs, PostDocs) whose main projects are aligned with the topic of the course. Thus, the designated CoCCoN-Fellow will provide an important contribution to the success of the planned CoCCoN-Q-Course (see details below), by accompanying it together with selected PIs.

Integrated Student Training Group

(CoCCoN-Q-Course/Q-Kolleg: "Cooperation & Collective Cognition")

An integral part of the proposed activity is the embedding of a structured research-based training program for graduate students, in cooperation with Q-Program by bologna.labs at HU. The course shall consist of a group of 12-16 students (equal number from PU and HU) and is supposed to last 12 months in between the two workshops. The course will consist of three parts: (1) literature study, (2) an introductory module on computational tools for data analysis and modeling of complex systems with practical computer exercises, and (3) the core activity of independent student research on self-determined miniature projects on cooperation & collective cognition.

In the first part the student will study and discuss selected relevant papers and recent scientific studies accompanied by an experienced researcher (CoCCoN-Fellow, senior PhD, Postdoc, PI). The discussion of the literature shall take place in an (electronic) journal club format using web conference tools. In the second part, the students will participate in a brief introductory course on selected aspects of modeling complex systems and data analysis. This practical part will be based on already existing courses at the different departments at both universities, and shall be used specifically to develop new electronic material and computer based exercises, which can be used beyond this specific activity. The most important component of the CoCCoN-Q-Course will be independent student project, related to the ongoing and recent research of the involved PIs/Fellow. They will be pursued in small, mixed teams of 3-4 students (Q-Teams). The students shall develop their own research questions involving development of scientific hypotheses, which can be tested either by a theoretical study (model development & simulations) or by (re-)analysis of existing empirical data. Also small low-cost field studies on complex contagion or cooperation can be considered. In the end, the results of the independent research shall be put into a small compilation of short manuscripts from each Q-Team and a presentation during the second workshop. The selection of the students will take place before the first workshop. The selected students are expected to participate in the two research workshops, with the first meeting being at the start of the CoCCoN-Q-Course giving the opportunity to the students to get to know each other and receiving general introduction into the research questions. The second workshop is intended for finalization of the individual miniature research projects and presentation of the results. In between the workshops individual groups will have regular meetings using E-conferencing tools. Here, a contact has been established with the bologna.labs and previous experiences with international Q-Courses as well as possible details of a CoCCoN-Q-Course were discussed. The bologna.lab team has agreed to provide full support in terms of infrastructure and didactic methods for the planned activity.

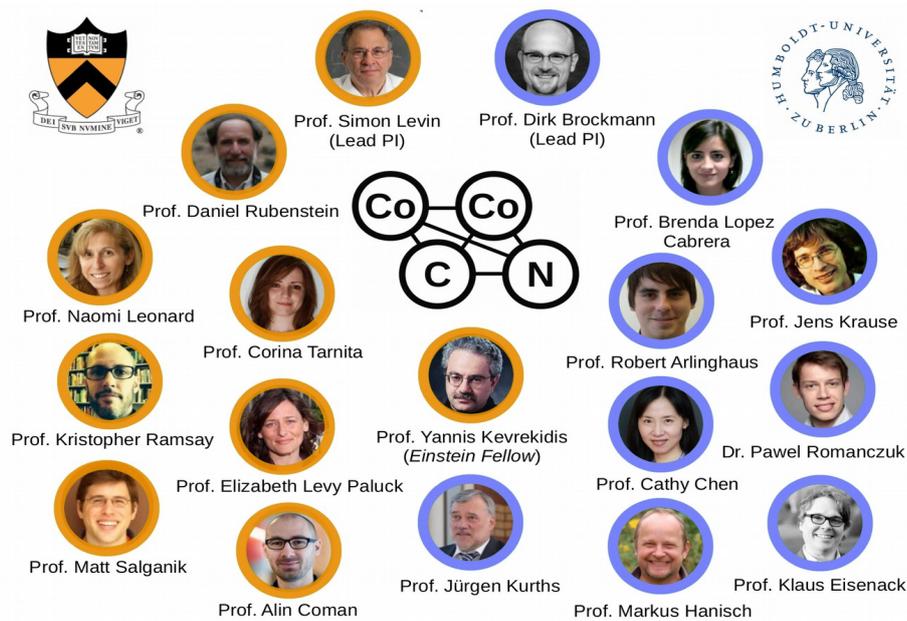


Illustration 2: Full list of principal participants of CoCCoN from both partner institutions.

Principal Investigators, Research Contributions and Institutional Collaborations

The network is formed by a highly interdisciplinary group of researchers from both universities. We have paid particular attention to a balanced mix of PIs across all career levels, starting from early-career faculty members and junior group leaders from both institutions, up to senior faculty. The group of principal participants consists of empirical ecologists, who will provide high resolution data sets of animal and interacting animal-human systems, experts in applied mathematics and theoretical physics, who will contribute state-of-the-art data mining techniques, network analysis methods and modeling expertise for studying cooperation and behavioral contagion processes, economists with a strong background in statistics and an interest in complex financial networks, psychologists with a strong empirical background and expertise in collective dynamics and social norms, and last but not least, social and political scientists with strong theoretical and quantitative empirical background, which will add unique application fields to our initiative (social norms in conflict resolutions, social networks & computational social science).

The lead participants of CoCCoN will be **Dirk Brockmann** at HU and **Simon Levin** at PU. Prof. Brockmann is a mid-career tenured professor at the Department of Biology, and an expert in diffusion and contagion dynamics on networks and head of the “*Epidemiological Modeling of Infectious diseases*” lab at the Robert Koch Institute. Prof. Simon Levin is a senior professor at Department of Ecology and Evolutionary Biology, a luminary in theoretical ecology, with a wide expertise encompassing population models and evolutionary game theory, who reached highest honors including the National Medal of Science for unraveling ecological complexity.

Further principal participants from the Princeton side will be (alphabetical order): **Alin Coman** (Dept. of Psychology), whose research interest include social norms and collective beliefs, and whose lab integrates a wide range of methodologies including laboratory experiments, field studies, and agent-based simulations; **Yannis G. Kevrekidis** (Dept. of Chem. and Biol. Engineering), a senior expert in multi-scale modeling complex systems and novel data mining and analysis techniques. He will be also partly based in Berlin as an Einstein Fellow during the funding period of the network; **Naomi E. Leonard** (Dept. of Mech. and Aerosp.

Engineering), who brings in expertise in dynamics and control of multi-agent systems and mathematical modeling of collective decision making in dynamic networks; **Elizabeth Levy Paluck** (Dept. of Psychology), her main research interests are: impact of mass media and interpersonal communication on tolerant and cooperative behaviors and evolution of social norms and behaviors in real world settings; **Kristopher Ramsay** (Dept. of Politics), his research focuses on the role of information and beliefs in cooperation both between individuals and social groups; **Daniel I. Rubenstein** (Dept. of Ecol. & Evol. Biology), his main research interest is decision making in animals. He aims at revealing general principles underlying complex patterns of behavior, by simple mathematical models and data gathered in the field and to exploring the spread and use of information across social networks, especially dynamic ones; **Matthew J. Salganik** (Dept. of Sociology), his research interests include social networks, quantitative methods and innovative web-based social research; **Corina E. Tarnita** (Dept. of Ecol. & Evol. Biology), who is interested self-organized behavior across multiple scales, from the emergence of multicellularity to large scale pattern formation. Her expertise is primarily theoretical but her lab combines theoretical and experimental approaches.

Members of CoCCoN on the HU side will be (alphabetical order): **Robert Arlinghaus** (Thaer Institute/IGB), who studies the interactions and feedbacks in capture fisheries using social-ecological research approaches. He links social-psychology, economics, ecology, evolution and movement ecology in integrated models of recreational fisheries, combining empirical and theoretical research; **Cathy Y. Chen** (School of Economics), her primary research interests are the problem of imprecise methods in finance, market risk and credit risk models and data mining of economic big data; **Klaus Eisenack** (Thaer Institute) who is a newly appointed professor for resource economics, interested in co-evolution of resources and institutions, polycentric climate governance, adaptation to climate change and energy transition; **Markus Hanisch** (Thaer Institute), an agricultural economist and an expert in the study of collective action and self help organizations. His research covers a wide range of related topics and focuses on the institutional prerequisites for collaboration and the measurement of impacts of collective action; **Jens Krause** (Thaer Institute), an expert in collective behavior and collective decision making in animals, in particular fish, as well as social network analysis of animal groups. He is also head of the Department of Fish Biology and Ecology at the IGB Berlin; **Jürgen Kurths** (Dept. of Physics) whose main interests are non-linear dynamics and theory of complex networks, with wide-ranging applications from climate to physiology. He is head of the research domain 'Transdisciplinary Concepts & Methods' at the Potsdam Institute for Climate Impact Research; **Brenda Lopez Cabrera** (School of Economics), her research interests are, among others empirical and computational finance and applications within the field of statistical analysis of insurance, finance and energy, with a focus on economic risk of natural hazards and energy markets; **Pawel Romanczuk** (Dept. of Biology), who starts an Emmy Noether research group on theory of collective behavior in biology. His main interests are, individual based stochastic models for collective behavior, coordination and cooperation.

Advisory Board & Further Collaborations

Apart from the principal participants listed above, there is also a number of senior researchers, who are strongly interested in the planned activity and the topic of the network. They will accompany the collaborative activity and provide scientific advice. In particular, they will provide additional expert discussion opportunities for junior researchers within the network. This **CoCCoN advisory board**, shall include:

- **Wolfgang Härdle** (Economics/HU), Ladislaus von Bortkiewicz Chair of Statistics, an expert in economical statistics and modeling,

- **Lutz Schimansky-Geier** (Physics/HU), an expert on stochastic dynamics, synchronization, agent based models and complex stochastic spreading phenomena. He is a retired professor and an active senior advisor at the Humboldt Universität zu Berlin,
- **Peter Hammerstein** (Biology/HU), an expert on evolutionary game theory and theoretical ecology. Prof. Hammerstein currently plans to focus his activities within the Dept. of Biology/HU on supervision and guidance to junior research groups,
- **Igor Sokolov** (Physics/HU), an expert on transport phenomena in complex media (e.g. networks) and nonlinear dynamics,
- **Henry Horn** (Biology/Ecology, PU), emeritus professor at the Dept. of Ecology and Evolutionary Biology with wide research interests in theoretical and experimental ecology and biology,
- **Johan Rockström** (Environmental Science, Stockholm Resilience Center) the executive director of the Stockholm Resilience Center and internationally recognized expert on global sustainability issues. In 2015, he was awarded the prestigious International Cosmos Prize.
- **Iain Couzin** (Biology/MPI for Ornithology), the director of the Dept. of Collective Behavior, Max-Planck Institute in Konstanz/Radolfzell. He is an international expert in the field of collective behavior and closely linked to Princeton university where he was full time faculty until last year.

An important partner of CoCCoN will be the Department of Collective Behavior, MPI Konstanz/Radolfzell, headed by Prof. Iain Couzin, who agreed to participate in our network activities with interested graduate students and postdocs from his department. This collaboration will provide important empirical input on collective cognition and complex contagion in animal groups. All corresponding traveling costs for MPI members will be covered by external funds of the MPI. Furthermore, via participants of the network, close links will be maintained to the Leibniz Institute for Freshwater Ecology and Inland Fisheries Berlin (IGB, Prof. Krause, Prof. Arlinghaus) and Potsdam Institute for Climate Impact Research (PIK, Prof. Kurths).

Long-term Development

Due to the size of the network and the topical focus, a natural continuation of the proposed activity is an application for an International Research Training Group (IRTG) financed by the DFG and the NSF. CoCCoN shall act as a nucleation point for a corresponding collaborative effort, and serve as a testing ground for such an IRTG in terms of possible challenges to such a long-term activity. We have established contact with the DFG and obtained detailed information on the time line of the Partnerships for International Research and Education (PIRE) by the NSF, which sets the frame for the co-funding with the DFG. The next call for our research division, where an application from within CoCCoN appears feasible will be in 2019, which aligns nicely with the duration of the project. It was confirmed by the responsible DFG officer, Dr. Sebastian Granderath, that a previous network activity, as proposed here, would significantly strengthen the chances of a successful proposal within the highly competitive selection process (approx. 15% success rate). Prof. Kurths and Prof. Härdle are participants who currently successfully lead IRTGs with Brazilian and Chinese partners, and who expressed their willingness to support the preparation of an IRTG application. At the level of undergraduate education our network will explore the possibility of enabling regular research internships for students interested in complex systems. Here, a contact exists with the German department of the Princeton University (Angiras Arya, aarya@princeton.edu; David Fisher, dtf@princeton.edu), responsible for the summer internship program in Germany. It is planned that Dr. Romanczuk will host this summer first interns from Princeton in his lab. Furthermore, we aim at establishing a regular exchange in between participating groups over a longer term. In particular, regarding short to mid-term visits for researchers and students at different levels of their career. Here we will popularize within the network

existing programs for exchange for undergraduate and doctoral students (e.g. RISE/DAAD, DFG), as well as postdocs and faculty (DAAD, DFG, Alexander von Humboldt & Einstein Foundation), in order to encourage continuation of the sub-group research beyond the funding of the network.

Integration and Internationalization - Benefits to Both Partner Universities

Humboldt Universität zu Berlin: The planned collaboration will not only integrate existing structures, but also significantly enrich the research portfolio and teaching activities of the participating units from HU. Beyond the general cross-disciplinary setting, bringing together Faculty of Life Sciences, School of Economics and Faculty of Natural Science. It brings also significant benefits regarding very timely and important academic infrastructure aspects. In particular, it will contribute to further integration of the newly formed Faculty of Life Sciences via a close collaboration of researchers from the Albrecht-Thaer Institute and Department of Biology. Furthermore, the topic of the network provides a unique possibility to integrate both Integrative Research Institutes (IRIs) at HU, which are represented within the network. On the one hand there is a clear connection to IRI THESys in terms of the thematic focus on the sustainability of socio-economic systems and regarding the possible application towards exploring cooperative behavior and behavioral contagion in the context of cooperation and sustainability. On the other hand the methodological background (mathematical modeling, networks and agent-based models) is clearly of high relevance to the IRI Life Sciences as well as the topic of evolution of cooperation. The proposed activity is also aligns well with the focus of the collaborative research center 649 “Economic Risk” and the International Training Research Group 1740 “Dynamical Phenomena in Complex Networks: Fundamentals and Applications”. Last but not least, the inclusion of an research-based trainings course will allow students from different disciplines to gather first international research experience in a creative and inspiring setting. In addition, the collaborative development of electronic teaching material will provide opportunities to exchange experience on teaching advanced courses using new media not only across disciplines but also across different academic cultures and for different frame condition at both institutions.

Princeton University: Our initiative is perfectly suited to further integrate existing structures for research and teaching. It will further strengthen the interdisciplinary connections, not only of the different participating departments, but in particular with respect to the integrated structures such as the Princeton Environmental Institute (PEI) and the Woodrow Wilson School (WWS). The topic of our network is highly relevant to both institutions and our activity would provide a new excellent opportunity for researchers to broaden their international network. By bringing in researchers with a strong mathematical background from engineering, applied mathematics and physics, we will further strengthen the quantitative focus of biological, social and psychological sciences - a unique selling point of the research performed at Princeton university. The timely topical focus on understanding cooperation and collective cognition across different real-world system, which goes beyond abstract, minimal models and reaches out across disciplinary boundaries by integrating empirical and theoretical research, will provide new stimulating impulses on how to combine empirical data with state-of-the art modeling approaches, a recurring challenge in modern science. Finally the planned collaboration with the Summer Internship program of the German Department to provide new research internship opportunities will extend the existing portfolio and make the internship program even more attractive to participating undergraduates.

Appendices:

- *Bibliography*
- *Tables with List of Participants from Princeton University and Humboldt Universität zu Berlin*
- *Principal Participant CVs (alphabetical order)*

APPENDIX – BIBLIOGRAPHY

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