



Project¹ Number: 859937

Project Acronym: i-CONN

Project title: Interdisciplinary connectivity: Understanding and Managing complex systems using connectivity science.

Periodic Technical Report

Part B

Period covered by the report: 01/10/2019 to 30/09/2021

Periodic report: 1st

¹ The term ‘project’ used in this template equates to an ‘action’ in certain other Horizon 2020 documentation

1. Explanation of the work carried out by the beneficiaries and Overview of the progress

1.1 Objectives

The primary goal of i-CONN is to educate and train a highly skilled team of ESRs specialized in the developing field of connectivity science. Our overarching aim is to overcome barriers to progress in using connectivity science to understand and manage complex systems by learning from transdisciplinary perspectives. Examples include: (i) determining how critical nodes shape the evolution of a system and how they can be manipulated or managed to alter system dynamics; (ii) deriving minimal models of structural connectivity (SC) and functional connectivity (FC) to capture their relations and identify the most relevant properties of dynamical processes, and (iii) to explore how shifts in network topology result in novel systems. To realise this potential, each research objective focusses on a specific challenge in developing connectivity science by learning from interdisciplinary approaches and transdisciplinary perspectives drawing upon our included disciplines as best helps achieve the objective:

Objective 1) Developing the theoretical underpinning of connectivity science for applications in complex systems.

Objective 2) Developing a unified framework of methods and approaches that can be applied across disciplines.

Objective 3) Exploring applications of connectivity science to understand, adapt to and manage complex systems.

These three objectives map directly onto Work Packages 1, 2 and 3 respectively. To avoid duplication, progress in achieving i-CONN's overarching three objectives is described in the explanation of work carried out per Work Package in the next section.

1.2 Explanation of the work carried per Work Package

1.2.1 Work Package 1, Development of a theoretical underpinning of connectivity research,

WP leader: Marc-Thorsten Hütt

Within i-CONN, Work Package 1 is devoted to the construction of a theoretical underpinning of connectivity research. Mathematical models of dynamics on graphs are tested and compared, in order to identify common principles. Two ESRs are directly associated with developing this theoretical underpinning: ESR 2 focusing on minimal models to explore relationships between structural and functional connectivity, and ESR 3 studying large-scale self-organized patterns on graphs and their dependence on network architecture. Several other ESRs contribute with their work to further aspects of Work Package 1: critical nodes (ESRs 1, 9, 12), resilience (ESRs 4, 8, 13), hot spots and hot moments in networks (ESR 10).

So far, we have reproduced known SC/FC correlations – the quantitative comparison of network architecture (SC) with a (network) representation of the dynamics (FC) – in minimal models (D1.1). We have shown that one can distinguish two classes of functional connectivity – one based on simultaneous activity (co-activity) of nodes, the other based on sequential activity of nodes – and that these two types of SC/FC correlations are of relevance to a range of application domains within i-CONN. This investigation has been driven by the work of ESR 2, with contributions of ESRs 1, 4, 5, 6, 8, 9, 10, 12, 15. It has been published in Royal Society Interface ([Voutsas et al., 2021](https://doi.org/10.1098/rsif.2021.0486)).

INTERFACE

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Review



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Two classes of functional connectivity in dynamical processes in networks

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Ronald Pöppel¹⁵, Christina Prell¹⁴, Sonia Recinos¹⁰, Yanhua Shi⁹,
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Figure 1 i-CONN's first ESR authored journal publication was published in October 2021

We are currently extending this work, employing symbolic encoding (Freund, 1997; Ebeling et al., 1996) and the analysis of Boolean attractors (Kauffman, 1969; Drossel, 2008) as techniques for better understanding the dynamical transformations underlying changes in SC/FC correlations. This is the core topic of the secondment of ESR 2 with partner EUC (involving ESR 7 at EUC).

Regarding self-organized patterns, ESR 3 has identified the three key models to focus on: (1) Turing patterns on graphs (as discussed in Nakao and Mikhailov, 2010), (2) avalanches (extending the model from Bak et al. (1987), such that it is applicable to erosion and sediment transport on hillslopes, thus preparing the secondments of ESR 1 at JACOBSUNI and ESR 3 at UDur, respectively), (3) wave propagation in excitable dynamics (using the SER model studied, e.g., in Messé et al. (2015); Messé et al. (2018)).

The main result of ESR 3 so far concerns the study of Turing patterns. Many real-life networks are incomplete and thus require the inference of missing edges via network inference algorithms (see, e.g., Hütt and Lesne, 2020). ESR 3 is exploring an alternative approach: completing an incomplete network by observing its collective behaviour. The results provide a link between Alan Turing's theory of morphogenesis (Turing, 1952) and network science (Barabási, 2016). Surprisingly, knowledge of a few collective (Turing)

patterns can allow the prediction of missing edges, even when more than half of the edges are missing. ESR 3 is currently preparing a manuscript for publication of these results.

Furthermore, within Work Package 1 we are now in the process of formulating minimal dynamical models (D1.2) motivated by the application scenarios to validate and theoretically understand the identified SC/FC relationships: (1) avalanches in a sediment transport model on hillslopes (collaboration between ESRs 1 and 3; see above); (2) model of contract dynamics between public institutions and private companies and signatures of corruption (collaboration between ESRs 3 and 4); (3) adaptation of the SER model for the interpretation of MEG and EEG data at AAISCS (collaboration between ESRs 3 and 11; see below).

For excitable dynamics, one driver of the organization of collective waves has been identified before in terms of the hub set orientation prevalence (Moretti and Hütt, 2020), which is a topological characteristic of edges in a network. Within i-CONN this quantity has been tested further in the context of neurobiological data (secondments of ESR 11 at JACOBSUNI and of ESR 3 at AAISCS). This investigation is an example of a synergy of methods within i-CONN (here: the time-delayed mutual information employed by ESR 11 together with the simple pattern-forming models employed by ESR 3) and the resulting methods are now being integrated in the Methods collection in WP 2.

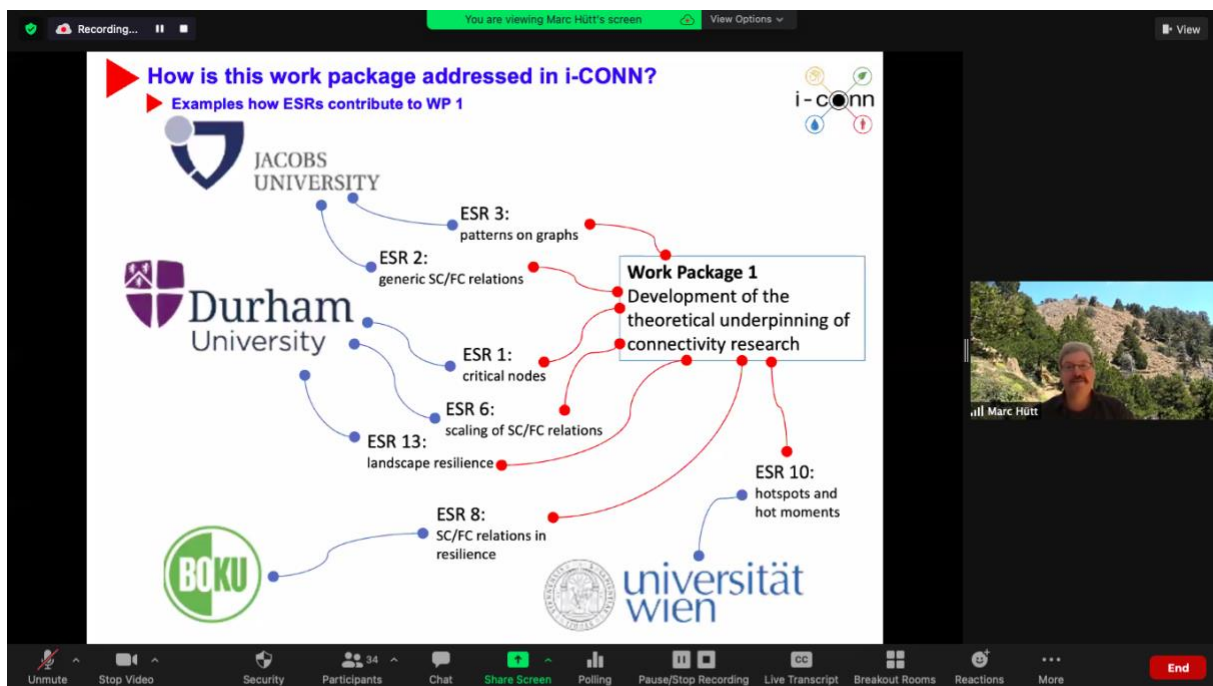


Figure 2 slide illustrating relationships within WP1

Summary (within the core topics contributing to Work Package 1):

- **Generic SC/FC relations.** Publication of the results ([Voutsas et al., 2021](#)) as a collaboration of 10 ESRs. Follow-up investigation is currently underway (collaboration ESRs 2 and 7).
- **Self-organized patterns on graphs.** One manuscript is almost ready (results by ESR 3). Further results have triggered collaborations of ESR 3 with ESRs 1, 4 and 11.
- **Critical nodes.** This topic was a focus of the Datathon event in September 2021 at AMU. Currently, the secondment of ESR 12 at JACOBSUNI is devoted to this topic.

We are in the process of formulating suitable modelling and data analysis approaches to address the other two topics of Work Package 1, (1) resilience and (2) hotspots and hot moments in networks.

Deliverables		
1.1	SC/FC correlations	Achieved, 10.06.2021
1.2	Minimal models	On track, due 30.11.2021
1.3	Evidence of SC/FC relationships	Due 30.11.2022

1.2.2 Work Package 2, Development of a unified framework of methods and approaches that may be applied across disciplines.

During the summer of 2021, the ESRs have been working on the implementation of objective 2.1 and towards objective 2.2 of WP2, which is the deep and thorough investigation and critical evaluation of existing connectivity methods in relation to the PhD topics of the ESRs. This task was essential for achieving milestone 5 (MS5), which is the evaluation of common connectivity methods. The task was realized through the implementation and submission of Deliverable D2.1, [Existing Methods](#).

The report summarizes existing methods that are used to assess connectivity in the various fields of science that are represented within i-CONN through 15 ESR projects and evaluates their applicability in problem solving. The methods are categorised either by research topic or applied approach: i) emergence and self-organization (i.e., community detection, patterns prediction and Stochastic Actor-Oriented Models as connectivity methods); (ii) critical nodes detection; (iii) measuring connectivity methods (through models of transport processes, indices of connectivity, and Correlation, Mutual Information frameworks) and (iv) Input and Output Analysis. For each method presented, we provided an introduction, specific related background, the problem that it addresses, important algorithms/framework addressing the problem, discussion of advantages/disadvantages of the existing methods, and available implementations. Additionally, and most importantly within the context of i-CONN, we discuss whether the connectivity methods described are interdisciplinary. The description and discussion of each problem ends with a demonstration of the application of one of the methods to some sample data set(s).

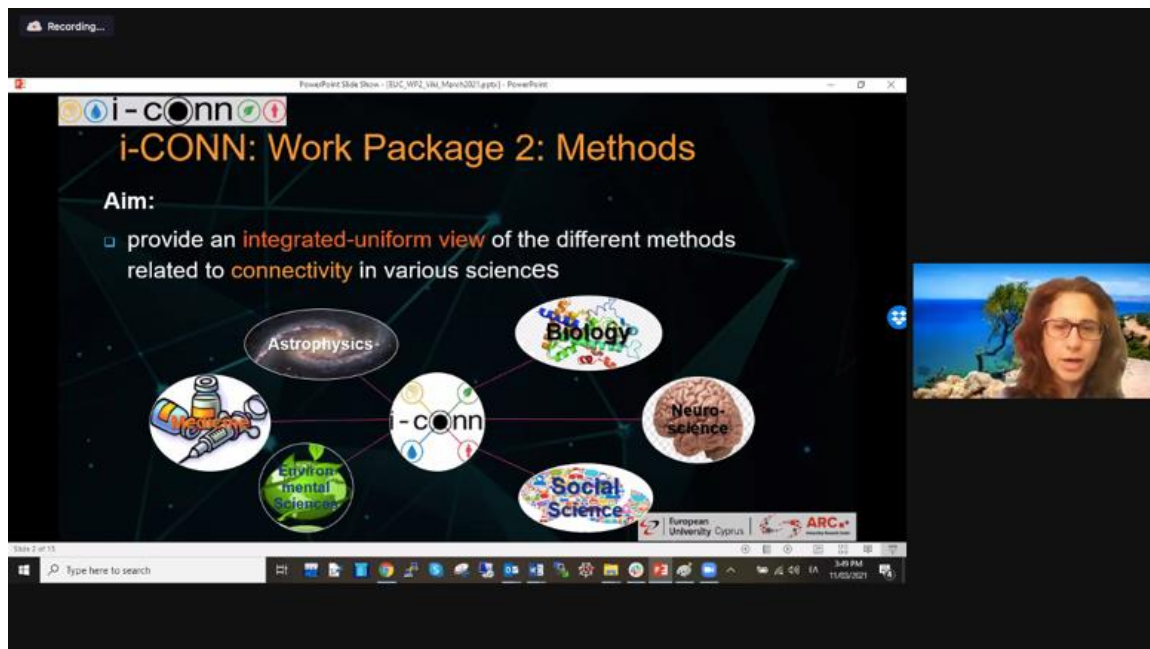


Figure 3. A slide from a WP2 discussion in March 2021.

A useful outcome of evaluating existing methods was that it forced the ESRs to reflect critically on the suite of network tools available within their primary discipline(s), and also across the wider disciplines represented in i-CONN and draw attention to certain domains where the existing tools are inadequate given the bespoke characteristics of their system of study.

The achievement of objectives 2.1 and 2.2 of WP2, has involved the ESRs studying the theoretical and technological background needed to understand the existing methods related to their PhD topic, focusing on the methods that have been previously employed in related problems but also considering connectivity methods that have been employed in other disciplines that might be applicable to their problem of study:

- ESR 1 investigated existing, and started developing, methodologies/algorithms to identify critical nodes weighted directed networks of dryland ecosystems.
- ESR3 investigated and implemented the method hub-set orientation prevalence (Moretti and Hütt, 2020) for detecting and quantifying long-range wave-like collective patterns.
- ESR 4 investigated descriptive analyses and stochastic models originating from Social Network analysis (SNA) to capture and explain structural patterns and tendencies, focusing on Stochastic Actor-Oriented Model (SAOM).
- ESR5 studied the use of the FC among the cortical regions to estimate either the pairwise wavelet-coherence or multitaper-coherence (Torrence and Compo, 1998) utilizing a temporal network representation (Holme and Saramaki, 2012).
- ESR 6 investigated numerical modelling of transport processes and indices of connectivity as connectivity methods, focusing on geomorphological and river systems.
- ESR 7 investigated community detection algorithms, focusing on their application for the study of galaxy evolution.

- ESR 8 explored graph theoretical modelling as well as various connectivity methods, such as the probability of connectivity index (PC) (Saura & Pascual-Hortal, 2007) to calculate the overall habitat connectivity and to detect the critical nodes in the Donau-Auen National Park, Austria.
- ESR9 investigated (Multi-regional) Input Output Analysis ((MR)IOA) as a connectivity method and its application in the environmental impacts of the global agro-commodity value chain network.
- ESR 11 studied correlation measures to estimate the similarity in various domains, such as Euclidean distance, correlation coefficient and Mutual Information measures, which can be used to quantify the common information between two random vectors, focusing on connectivity measures to calculate the exchange of information between the activity of the brain originated from spatially distinct regions in the brain.
- ESR 12 investigated Input-Output Analysis methods and its relevance to study connectivity science issues for assessing the dynamic temporal evolution of economic vulnerability to fossil fuels in several selected economies.
- ESR 13 investigated agent-based modelling, graph theoretical and social network analysis methods, focusing on (geo)archaeological contexts.
- ESR 14 explored models and methods employed for longitudinal modelling of Social Network data.
- ESR15 investigated connectivity methods, a domain-oriented method and a more generic method, for studying the pharmaceutical contamination processes in river networks.

The work accomplished will be utilized for the accomplishment of objective 2.2, which is the integration, classification, evolution and adaption of existing methods to an integrated uniform interdisciplinary scientific framework. The new classification and the theoretical framework will demonstrate in a transparent way how methods in various, sometimes disparate fields of science are related, showing commonalities and uniqueness, in terms of properties, structures, techniques the methods utilized.

Deliverables		
2.1	Existing methods	Achieved, 18.10.2021
2.2	Connectivity methods across disciplines	On track, 31.05.2022
2.3	Synthesis of methods	Due 31.05.2023

1.2.3 Work Package 3. Exploring applications of connectivity science to understand and manage complex systems.

WP3 focuses on the applications of connectivity science and the relation of applications to theory and method development. WP3 will be informed by our non-academic partners, AAISCS, the Environment Agency and IIASA. The WP started with the evaluation of cross-

disciplinary applications of methods, targeting milestone MS6, supported by MS1 (potential scoping via online meeting) and MS4 (joint database development).

The first task 3.1, concerning transferrable method identification, contributed to the development of Deliverable D3.1. The aim was to scope cross-disciplinary method applications, which builds on WP2's Deliverable 2.1 on methods. Whereas WP2 D2.1 has provided an overview of methods and example applications, D3.1 explores further how the range of methods can be applied to the potential range of suitable applications. This task and the related report D3.1 help to fulfil objective 3.3, testing the applicability, compatibility, and enhancement of consistent methods.

The first draft ideas to structure task 3.1 were presented and discussed at the Advanced Course 2 meeting (August 2021), which was the first network-wide hybrid meeting. 9 ESRs attended in person). The ESRs were asked to identify who among their peers would be working with methods that could be relevant for their own applications or vice versa. In addition, they had to briefly describe the methods they are using, including a brief literature review of the disciplines that their methods had been applied to so far, and some first ideas about applications that could be potentially relevant.

Two matrix table structures were proposed to provide a first outline and orientation of the task. One table proposed a collection of all relevant connectivity methods in a column, and all applications in a row, thereby helping to identify empty cells that could potentially be relevant for cross-disciplinary applications.

Given the different focus and emphasis on theory, methods, or applications of each ESR, another table suggested specific guiding questions for one of four types of ESR orientations: (A) A strong ESR focus on one type of method and one type of application suggests identifying at least one other method that could be relevant to analyse the empirical case chosen, contributing to mixed-methods research. (B) A wider use of multiple methods, focusing on one application, helps to evaluate the potential of other methods, whereas those ESRs whose objectives are more method-driven, focusing either on multiple applications of one method (C), and those also using multiple methods for multiple applications (D), may most easily anticipate the potential for cross-disciplinary applications, while also choosing the applications where they see most potential to test their method advancements. ESRs in the C and D quadrant can provide ideas to ESRs with a focus on specific empirical applications (A and B).

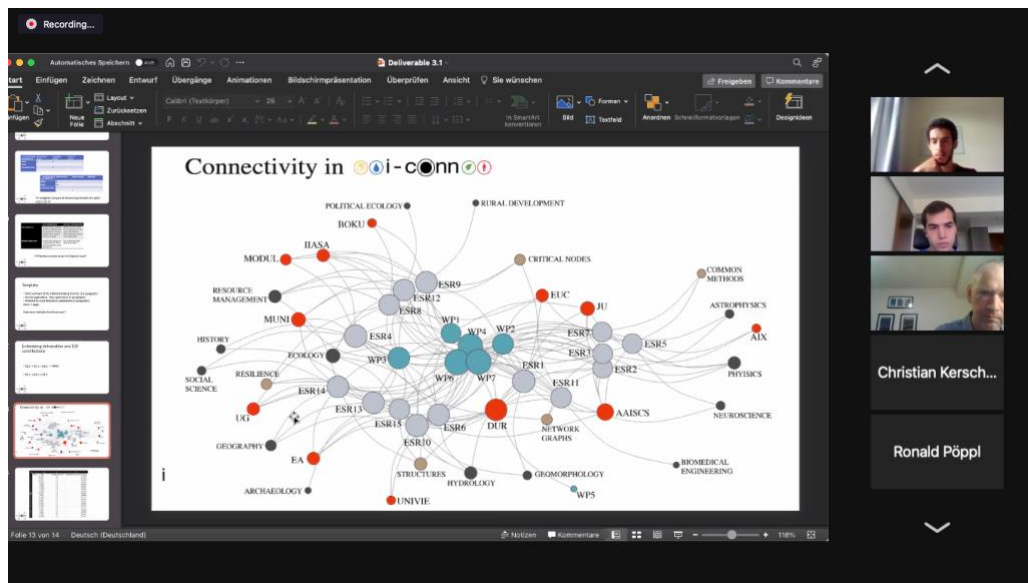


Figure 4. A screenshot from a WP3 discussion meeting.

Building on MS4 (Populating the ITN Database with disciplinary data) and the contributing Datathon, the ESRs then developed report drafts to assess the potential for cross-disciplinary applications of methods. Three working groups were formed with group 1 focusing on node importance led by ESR 1 (ecogeomorphology) with empirical contributions from ESR4 (political systems), ESR9 (social-ecological systems), ESR12 (energy flows), and ESR14 (social networks); a group 2 led by ESR3 (network theory) with contributions from ESR5 (neuroscience), ESR10 (sedimentology), ESR11 (neuroscience), and ESR15 (hydrology); and a group 3 led by ESR6 (fluvial geomorphology) with contributions from ESR2 (network theory), ESR7 (astrophysics), and ESR8 (ecology), focusing on the simultaneous use of datasets from the domain of ecology (Donau-Auen National Park) and the domain of astrophysics (Spectral Energy Distribution for different Galaxies).

When completed, the Deliverable D3.1 report will inform D2.2 on connectivity methods across disciplines, which will consider the common elements of a collection of manuscripts demonstrating the generalizability across disciplines. Simultaneously, the theoretical SC-FC relations developed in D1.1, will be tested and reported in D3.2 which will inform D1.3 on the empirical evidence of SC-FC correlations.

The secondments have also contributed to advancing the application-oriented objectives of WP3. ESR4's secondment with JU has led to the development of a joint project together with ESR3 to build and test minimal model connectivity approaches to public-private contract data in Latin America. This will be crucial when testing theoretical SC-FC relations, as reported in D3.2. The secondment of ESR14 at MU has focused on interdisciplinary approaches to modelling social-ecological networks, with a subsequent secondment at the EA in mind. Theoretical approaches have been discussed and potential methods drafted for an application case proposed by the EA, focusing on a Coastal-based approach (CoBA) to collaborative environmental governance. As ESR9 and ESR14 are both using social-ecological network approaches, the planned secondment of ESR9 at the EA has been postponed to coincide with ESR14's secondment. This helps to design a joint research strategy with an optimal

combination of methods for the application objectives and empirical research questions that have been suggested by the EA.

Deliverables		
3.1	Cross-disciplinary applications of methods	On track, due 01.12.2021
3.2	Testing of theoretical SC-FC relations	Due 30.11.2022
3.3	Links between theoretical relationships, methods and applications	Due 31.05.2023

1.2.4 Work Package 4. Training.

Work Package Four has eight objectives. Progress within each objective is described below.

i) To coordinate career-development plans and training-needs analyses across the network.

An i-CONN Training Best Practice [document](#) was prepared by the Training Manager and was approved by the Training Board. Templates for the Career Development Plans (CDP) and for Training Needs (TNA) were included in this document. Both the CDPs and the TNAs were produced as a Microsoft Form for completion by the ESRs in conjunction with their supervisors. CDPs and TNAs were prepared by all ESRs in the first few months of their employment. All ESRs have revised these documents in autumn 2021.

The TNAs and CDPs were discussed by the Training Board. Training needs that were identified as being broadly required were incorporated into the central training provision. For example, a course in Python was made available.

ii) To provide generic research-training skills following the Researcher Development Framework.

Generic research skills were delivered as follows:

- September 2020 – **CV Development.** A half day Zoom session by David Henderson, a Senior Careers Adviser at Durham University who is responsible for careers support to postgraduate research students and postdoctoral research staff.
- September 2020 – **Managing the student-supervisor relationship.** A half day Zoom session given by an external consultant, [Robin Henderson](#), who specialises in the Higher Education sector.
- September 2020 – **Open Data and FAIR Data Principles and Open Access Publishing.** A half day Zoom session led by James Bisset (Senior Manager in Library Research Services) and Nick Syrotiuk (Research Data Manager) both at Durham University.

- November 2020 – **Collaborative Working and Unconscious Bias**. An interactive Zoom session given by Michelle Taylor, Learning & Organisation Development Senior Manager at Durham University.

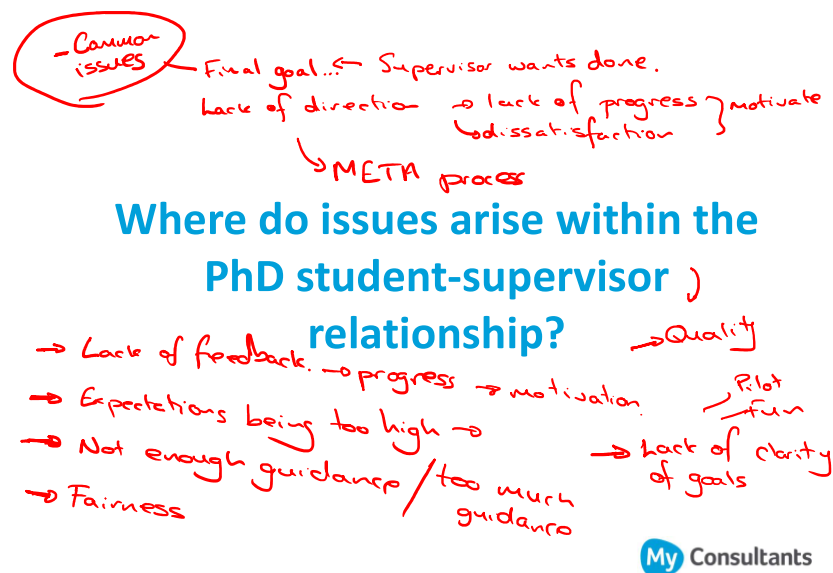


Figure 5 A slide from *Managing the Student-Supervisor Relationship*

- September 2021 (postponed from March 2021 due to presenter illness) **Networks, Teams, Interdisciplinary Collaboration and Research Impact**. Three interactive Zoom sessions delivered by an external consultant [Steve Hutchinson](#) who specialises in researcher development.

Positive feedback on the courses was given by the ESRs with the training in ‘Managing the student-supervisor relationship’ being particularly appreciated.

iii) *To provide transferable skills training on: (a) research integrity; (b) scientific writing; (c) communications and media skills and ensuring research impact; (d) entrepreneurship.*

In the first period of i-CONN the following transferable skills training was delivered:

- September 2020 – **Research Integrity & Ethics**, a half day interactive Zoom session given by David Heading, a trainer at the [Durham Centre for Academic Development](#).
- January 2021 – **Outreach & Engagement**, two interactive Zoom sessions one given by the Project Manager and one by an external consultant [Duncan Yellowlees](#), a communication expert.

- March 2021 – **Masterclass in Scientific Writing**, a three day online interactive workshop given by [EDP Sciences](#), a scientific publishing company.
- March 2021- **Social Media Training**, an interactive online session with [Lucy Clarke](#), who has extensive experience of delivering training in using social media to communicate science and promote research outcomes.
- September 2021- The **Networks, Teams, Interdisciplinary Collaboration and Research Impact** described above also addressed research impact.
- The Enterprise School is currently being arranged for June 2022. This will be delivered by the Durham Business School.
- A course entitled “dealing with the media” is planned for early 2023.

Where possible, the ESRs were sent copies of the presenters’ slides or have access to recordings of the training. Most of the training courses above were attended by all 15 ESRs.

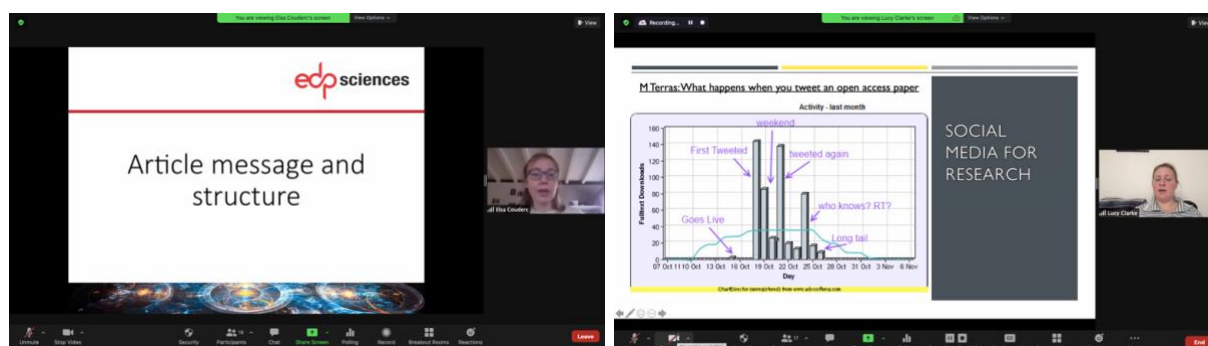


Figure 6. Slides from the training in scientific writing and social media skills.

iv) To provide specific training on research philosophy and project design for connectivity-facing projects and on interdisciplinary working:

An interactive online week-long course was held in September 2020 and delivered by Louise Bracken, John Wainwright and Tony Parsons. The course addressed: the Philosophy of Science; interdisciplinary research; models of communicating research; stakeholder engagement and framing of research, and Project Planning, including dealing with unexpected problems. All the ESRs were involved in planning projects and then had to deal with a “spanner” that was introduced as an example of a potential problem.

Project Planning Exercise

This is an exercise to make you think about how to plan your activities over the next three years. It is NOT about the academic content of the imaginary project you will be given. The idea is to make you think about all the things that go to make up a PhD project and how they can be successfully fitted into a three-year period.

You may know nothing about the topic you have been assigned or the methods you will need to use. For the purpose of this exercise it is not about the topic or the methods, but how you plan to acquire the skills, knowledge And data that you will need to complete the project

You are a group of 3, but you need to interact to behave as a single person doing the project



Figure 7. Project planning was taught through a practical exercise.

v) *To provide overview training on introducing methodologies used in connectivity in different disciplinary areas.*

During the network meeting in March 2021, i-CONN investigators delivered introductory lectures in the use of connectivity in different disciplines:

Connectivity Methods in Biology and Medicine, Marc-Thorsten Hütt

Connectivity in Neuroscience, Demian Battaglia

Connectivity methods in Astrophysics, Andreas Efstathiou

Fundamental concepts, simple and complex computations of connectivity methods in neuroscience and their translational prospects on earth and in space, Andreas A. Ioannides

In addition, Andreas Ioannides delivered an online introductory course in magneto- and electroencephalography.

We have established a seminar series to introduce the consortium to a range of different methods, and application areas.

- Professor Yamir Moreno (Advisory Board member): Data driven modelling of the COVID-19 pandemic.
- Professor Ginestra Bianconi (Advisory Board member): Multilayer networks: structure and function.
- Professor Martin Everett (Advisory Board member) A short tour of social network analysis.
- Professor Tony Parsons: Hillslope processes: a connectivity perspective.

- Professor Paul Spirakis: The impact of temporal availability patterns on dynamic networks.
- Professor Shlomo Havlin: Network Science and Applications.
- Professor Dirk Helbing: How networks can change everything for better or for worse.
- Professor Fragkiskos Papadopoulos: 12 years of network geometry: from single layer systems to multiplexes and temporal networks.
- The Resilience Symposium – a research symposium with mini presentations from four speakers and organised by Christina Prell.

vi) To develop a “Datathon” to develop appropriate ways of integrating connectivity data and enabling their efficient analysis.

The Datathon was delayed, with the permission of the Project Officer, to maximise the likelihood of the ESRs attending in person. The Datathon was held in Marseille in late September 2021 and was organised by Demian Battaglia and was supported by Tony Parsons and Marc Hütt. The ESRs collaborated in small teams to work on each others’ data.



Figure 8. One of the Datathon teams in discussion.

The team pictured above studied the datasets provided by Sonia and Michalis (astrophysical and ecological data) and applied the coding skills of Selim and Venetia to provide a theoretical point of view to support the analysis of the data. In the image above, Sonia is describing the main concept of her project and the usefulness of her data to find not only the best way to handle them but also common methods that could be applied to Michalis' data, too. Tony Parsons, Chair of the Supervisory Board, advised the team on how to design their project.



Figure 9. Datathon Team discussing critical nodes.

Harald, Shubham, Mario, Yanhua and Marcel (Figure 9) worked on the topic of important/critical node identification. They tested identification procedures such as node removal and specific efficiency measures (global/local/nodal) on the different datasets that they are working with in their PhD projects, which span geomorphological as well as a variety of socio-economic data.

vii) To provide specialized training on methods in: (a) network and social network analysis; (b) connectivity in environmental science; (c) Graph theory; (d) Input-output analysis; and (e) Novel Approaches to Collecting Data in Connectivity Science.

ESRs have received training at their own institution as needed to support their PhD studies. This institution-level training has been informed by the Training Needs Analysis completed yearly by each ESR. In addition, training in core areas was provided to all the ESRs. The impact of the pandemic meant that there was a move from delivering training as part of the scheduled i-CONN events to spreading training activities over a wider time frame using videoconferencing.

The following training was delivered:

- Network and Social Network Analysis

Christina Prell delivered 6 hours of introductory social network analysis training by Zoom in autumn 2020. This allowed the ESRs the opportunity to address any gaps in their knowledge in advance of the Brno residential training course. The sessions were recorded and are available to the ESRs on the website.

A seven-day training course “Network and Social Network Analysis” was held in Brno, Czech Republic 18 – 25th August inclusive. The Course was run in a hybrid format as some ESRs were unable to travel due to national/institutional COVID regulations. Nine ESRs attended in-person. The remaining ESRs attended via Zoom. This was a landmark event for i-CONN as the pandemic had stopped the ESRs from meeting as a group or enabled them to meet some of the network investigators from other institutions.



Figure 10. The Advanced Course in Brno was the first hybrid event.

The training was organized and delivered by four i-CONN investigators: Christian Kimmich (Masaryk University), Christian Kerschner (Modul University), Christina Prell (University of Groningen) and Brian Fath (IIASA) - one of i-CONN’s partners. Additionally, training was delivered by five external experts.

This training course was a challenge to deliver as it was our first hybrid event. However the training was well received by the ESRs who particularly enjoyed the hands-on training exercises in ecological network analysis given by i-CONN partner, Brian Fath and on model building in RSiena.

- Connectivity in Environmental Sciences

This course has been organised for February 1 - 4th 2022.

- Graph Theory

An introductory six-part introduction to Graph Theory was delivered by Zoom to the ESRs over winter 2020/21 by Vicky Papadopoulou Lesta.

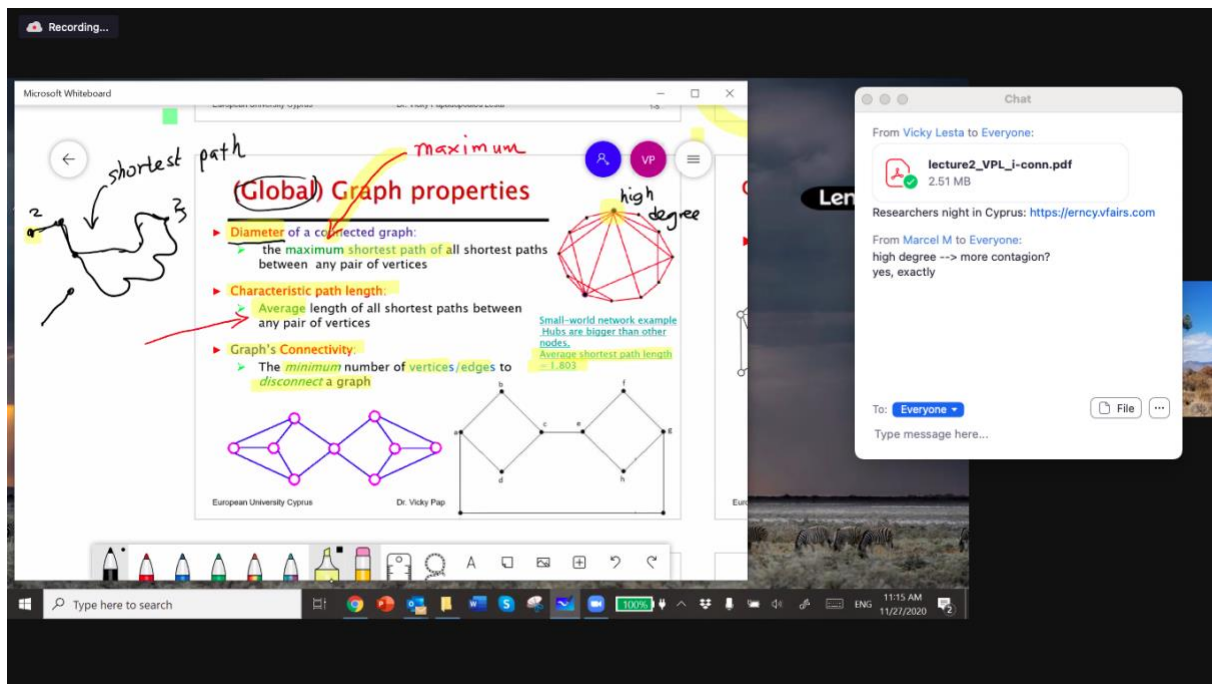


Figure 11. A slide from the Introductory Graph Theory course, attended by all the ESRs.

A three-day advanced course “Connectivity Methods and Graph Theory” was delivered in March 2021 by Zoom, also organised by Vicky Papadopoulos Lesta. This involved training sessions delivered by four experts including three external speakers. In addition, four consortium members delivered an overview of the application of connectivity methods to their own discipline.



Figure 12. The introductory slide from the online Advanced Course held in March 2021.

- Input-Output Analysis

The ESRs were introduced to Input-Output Analysis at the seven-day “Network and Social Network Analysis held in Brno in August 2021, see a) above.

- Novel Approaches to Collecting Data in Connectivity Science.

This course is scheduled for March 28th – 31st 2022.

viii) To coordinate workshops and seminars to feedback on ongoing training progression.

Training Feedback is requested both by asking for information via a Microsoft Form and by the ESRs’ representative on the Training and Supervisory Boards. The Training Board reviews the feedback that is received after each training event.

Deliverables		
4.1	Training Approaches (Handbook)	Achieved , 19.12.2019
4.2	Research Philosophy, Project Design and Methodology (training course)	Achieved , 30.09.2020
4.3	Working on Interdisciplinary Topics (training course)	Achieved , 30.09.2020
4.4	Introduction to connectivity methods and Graph Theory (training course)	Achieved , 29.03.2021
4.5	Datathon (event)	Achieved , 07.10.2021
4.6	Network and Social Network Analysis (training course)	Achieved , 26.08.2021
4.7	Connectivity in Environmental Sciences (training course)	On track
4.8	High-resolution scanning (training course)	On track
4.9	Key Skills	On track, parts i) and ii) delivered

1.2.5 Work Package Five. Management.

Four Boards were established, as described in the Grant Agreement, to oversee the successful running of i-CONN:

- Management Board, MB. This oversees the general successful running of i-CONN and includes the lead scientist from each Beneficiary as well as the Chairs of the Training Board and Supervisory Board. It has met ten times in the reporting period.
- The Supervisory Board, SB. This is the ultimate decision-making body within i-CONN and oversees all activities of the Consortium. The membership is comprised of

the Scientific Coordinator, the Training Manager, the Work Package leaders, the principal investigators from the non-academic beneficiary/partner organisations and an ESR Representative. The Chair of the Advisory Board is also invited to the SB meetings. The Board has met five times within the reporting period.

- The Training Board, TB, whose membership includes the Training Manager, three academic PIs, one non-academic PI and an ESR, has met five times in the reporting period.
- Advisory Board, AB. i-CONN established an [Advisory Board](#) after asking for nominations from the consortium and then seeking to establish a membership that reflected the diverse nature of i-CONN. Initially four members were invited, with Professor Jacky Croke as Chair, but an additional two members have been invited to maximise the prospect of securing attendance of AB members at i-CONN annual meetings. Currently, Professor Martin Everett is acting Chair while Professor Croke is on secondment in Australia.

A Project Manager was recruited at Durham University. She started working part-time for i-CONN in January 2020 and was full time by July 2020. The Project Manager attends all the above Board meetings and therefore has an overview of all aspects of i-CONN.

At UDur the Coordinator, Project Manager and Training Manager are in regular correspondence, by email, Slack, Zoom, Teams and in person. The Management team at Durham also maintains regular contact with the WP leaders and with the organisers of training courses and network events.

Slack is also used for informal network communication, for sharing recommendations of external resources such as events and scientific papers and for providing channels to discuss work packages and specific i-CONN events.

Work Package Five has nine objectives. Progress within each objective is described below.

i) To implement financial management of the network.

A preliminary in-person meeting of the consortium in November 2019 was attended by a European Finance officer from Durham University. He delivered a presentation introducing the consortium to the finances and financial reporting of an ITN. Subsequently the Project Manager has been available to deal directly with queries from the consortium. Additionally, she delivered a presentation on finance and eligible costs at the first annual workshop in September 2020 that was attended by all PIs and ESRs. This was followed by an additional presentation “ITN Finance for ESRs” in July 2021.

ii) To oversee the five network meetings and training workshops.

In the Reporting Period there have been two network meetings: the first annual workshop in September 2020 and the second annual workshop in March 2021. Both workshops were virtual events because of the COVID-19 pandemic and were attended by all PIs and ESRs as

well as additional members of the consortium. Presentations were recorded and stored on the website. The ESRs gave presentations about their projects at both workshops.

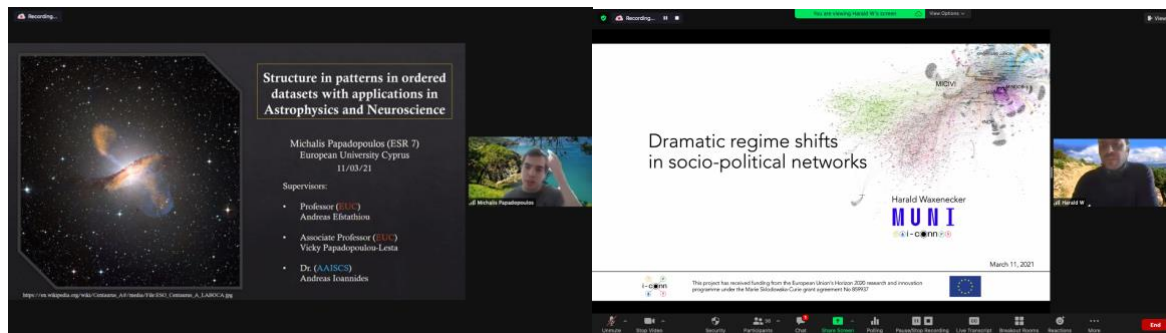


Figure 13. All ESRs gave presentations about their research. These slides are from ESR 7 and ESR 3.

A

iii) To recruit 15 ESRs and ensure delivery of relevant training.

Fifteen ESRs were successfully recruited. Despite the difficulties caused by the COVID-19 pandemic, all ESRs were in post within four months of the originally planned recruitment date. At the preliminary meeting of the consortium in November 2019 the PIs discussed recruitment plans and training in recruitment practice was delivered including unconscious bias training. The PIs remained in regular communication with each other about recruitment and pooled information about suitable candidates. During the recruitment period all posts were advertised on Euraxess, the i-CONN website and on the FindaPhd website. Further details about the ESRs' training are included in the WP4 report above.

iv) To oversee submission of all Researcher Declarations and Conformity.

The Project Manager guided the PIs through the Research Declaration process and all declarations were signed in time. Likewise, guidance was given both at Management Board meetings and via direct emails from the Project Manager about the recruitment procedure, including the eligibility of prospective ESRs.

v) To ensure timely achievement of deliverables.

All Deliverables in the Reporting Period have either been met or permission to delay the deliverable date has been sought from the Project Officer. Documents have been uploaded to the Participant Portal in all cases.

vi) To ensure timely reporting on main network activities.

A Progress Report was submitted in Month 13 as required. The Report was approved by the Management Board before submission.

vii) To provide conflict resolution within the network.

Conflict Resolution has not yet been required. The Consortium Agreement clearly states the obligations of the beneficiaries and partners towards each other and has a paragraph

addressing the settlement of disputes (11.8). The PIs are regularly reminded of the need to report problems to the Management Team as quickly as possible and the ESRs know that they can speak to the ESRs' representative on the SB or to the Project Manager in case of conflict with their supervisor.

The regular meetings of the i-CONN Boards alongside activities such as the workshops and seminars ensure that communication within the consortium is strong. Additionally, i-CONN has encouraged good practice by producing an '[Authorship Plan](#)' to determine i-CONN policy on the ownership and authorship of outputs including publications and datasets.

viii) To provide contingency planning and implementation of contingency plans including transfer of resource in order to enhance the impact of the network.

Contingency planning has been undertaken continuously by the MB and the SB and has been needed to deal with the effects of the pandemic. The TB has also been involved in deciding how to rearrange and optimally deliver training in the light of COVID-19. In the case of each workshop or training activity a decision was made at approximately six weeks before each meeting whether the meeting would proceed in-person, online or in a hybrid format to allow adequate planning.

Although risk management has been undertaken as a matter of course throughout the Period, formally assessing the risk register has been established as a permanent agenda item for Management Board meetings.

ix) To launch and maintain the network's website.

The DU Management Team commissioned a website <https://iconn.network> from a local web design company. The website is both outward facing and used for the confidential use of the consortium.

A [website](#) was established in the early months of i-CONN (6.2.4). It was used to advertise the ESR vacancies and acts both as a source of information for the consortium, for example storing minutes of meetings and recordings of seminars, but also acts as an outward facing means to communicate with the wider public.

Deliverables		
5.1	Start recruitment of ESRs	Achieved, 01.12.2019
5.2	Launch website	Achieved, 30.10.2019
5.3	Network meetings	On track. Kick-off meeting and two annual meetings completed.
5.4	Management Meetings	On track. All minutes on website.
5.5	540 months of ESR Training	On track.

5.6	Final Report	Due December 2023
5.7	Awarding of Doctoral Degrees	On track.
5.8	Consortium Agreement	Achieved, 04.03.2020
5.9	Supervisory Board of the network	Achieved, 01.12.2019
5.10	Progress Report	Achieved, 30.10.2020

1.2.6 Work Package 6. Creating transdisciplinary capacity and uptake of research outcomes generated by i-CONN.

Work Package Six has three objectives and progress in each is described below.

i) To generate the transdisciplinary capacity required to sustain the i-CONN network.

A [protocol on transdisciplinary practice](#) (6.1.1) was prepared by Louise Bracken, WP6 leader and a Transdisciplinary Management group (TMG) was established with a [terms of reference](#) (6.1.2). Chaired by Louise Bracken, the membership of the committee includes two academics, two ESRs and a representative from a non-academic partner. The Coordinator and the Project Manager also attend the meetings. The membership reflects the disciplinary diversity of i-CONN. The TMG will establish a transdisciplinary session at future i-CONN annual meetings and have agreed that these events will include professional videorecording of talks given by the ESRs, for public engagement via the website, and a Panel discussion with external members.

The i-CONN consortium has representatives from an extremely diverse range of disciplines and in itself provides a rare opportunity to study the evolution of a transdisciplinary consortium. The TMG has initiated gathering the data that will be required to study the transdisciplinary activities of the consortium (6.1.3). A set of questions about transdisciplinarity has been included in the secondment report template that is completed by every ESR after each secondment. In addition, the training feedback questionnaire that is sent to ESRs after each training event includes questions about transdisciplinarity. This work is led by WP6 leader, Louise Bracken. ESR 14 will also include a study of i-CONN in his PhD research. He has established a survey that gathered data from the members of i-CONN before the annual workshop in March 2021. A second survey has recently been sent to the whole consortium.

ii) To manage the research, communication and dissemination and impact activities.

i-CONN's first ESR-authored paper was published in October 2021 in Royal Society [Interface](#). This transdisciplinary publication was led by ESR 2 but involved contributions from ten ESRs and fourteen investigators from eleven i-CONN institutions. Fifteen papers are currently in preparation and we expect to produce the planned thirty journal papers (6.2.1) from i-CONN research. A special issue of papers (6.2.2) and an edited book (6.2.3) will be discussed at a network meeting in December. These activities will commence in the next Period of i-CONN.

The ESRs each have a dedicated [page](#) on the website for publishing short articles in their ‘research journals’. Articles range from ESRs explaining connectivity science to reporting on training activities. The ESRs have produced two [newsletters](#) which are also available on the website. A different team of ESRs produced each newsletter.

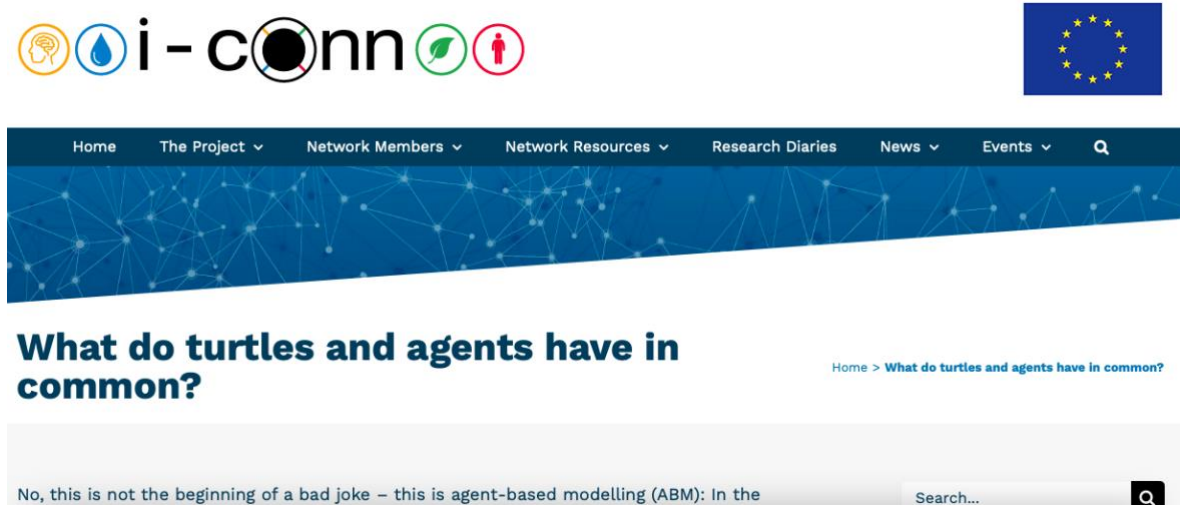


Figure 14. The ESRs post articles that explain their research or discuss their experiences as an ESR.



Figure 15. The first i-CONN newsletter included articles by five ESRs, the Coordinator and the Project Manager.

An i-CONN brand identity was developed by the coordinating institution at the same time as the website was commissioned and is used in i-CONN presentations.

i-CONN also has an active [Twitter account](#) @network_iConn. The ESRs have established a rota for managing the Twitter account but all members of the consortium can contribute.

The consortium produced a [plan](#) for the exploitation and dissemination of results in June 2021 (6.2.5). The dissemination and exploitation of results is a standing agenda item at Management Board meetings and should become more important in the second Period of i-CONN as ESR research develops.

As well as advertising seminars on the website, we make use of the connections of the i-CONN consortium to advertise events to a wider audience. Seminars have been attended by senior personnel from such diverse agencies as Public Health England and the Indonesian Ministry of Agriculture. We will continue to advertise our activities through these networks.

Maximising the impact (6.2.6) of i-CONN research will become more important in the second Period, but we have established the practices, described above, that will facilitate this in the future. In addition, we have an Advisory Board to give external opinion on how we maximise our impact. We have good links to the Partnership and Engagement team and the Commercialisation team at Durham University and similar professional support exists at other i-CONN institutions.

Although Louise Bracken is no longer head of the Institute of Hazard, Risk and Resilience (IHRR) at Durham University, i-CONN is still closely linked with the IHRR (6.2.7). i-CONN activities are advertised to the extensive, and global, IHRR mailing list. One of the IHRR co-Directors, Dr Sim Reaney, has joined i-CONN as a co-supervisor of ESR 15.

iii) To facilitate the uptake of research by the stakeholders.

The uptake of i-CONN research will become important in Period 2. However, we have established contacts and links with stakeholders, for example the inclusion of the UK Environment Agency as a Partner in the network. The consortium members have a huge range of contacts amongst policy makers (outlined in the [Dissemination and Exploitation](#) report) which will facilitate the exposure of i-CONN's research amongst potential users. The wide advertising of i-CONN's seminars has already shown the reach of some of the networks we have access to.

Deliverables		
6.1	Transdisciplinary Protocol	Achieved, 01.12.2020
6.2	Transdisciplinary Management Group terms of reference	Achieved, 01.12.2020
6.3	Project Report on transdisciplinary Management Group	Not due until 01.06.2023
6.4	Transdisciplinary Practice for Connectivity Science	Not due until 01.06.2023
6.5	Final Communication strategy	Achieved, 01.12.2020
6.6	i-CONN Project website www.iconn.network	Achieved, 01.12.2020
6.7	Final Dissemination and Exploitation Plan	Achieved, 01.06.2021
6.8	Policy Briefings	Not due until 01.06.2023
6.9	Communication, dissemination and impact activities	On track. Deliverable not due until 01.06.2023

1.2.7 Work Package 7. Open Research Data

The objective of our data management plan is to make our data findable, operable, accessible, interoperable and reusable following FAIR principles. To expedite this, we organised training for the ESRs, ran a Datathon event in late September 2021 and prepared a Data Management Plan that will be re-evaluated in early 2022. These actions are all described elsewhere in this report. The delayed start for many of the ESRs, the impact of the pandemic on conducting

experiments and fieldwork, and the delayed Datathon mean that we are only now generating new data. A GitHub account was opened to allow the sharing of code.

1.3 Impact

Section 2.1 of the DoA is still relevant and does not need to be updated.

2. Update of the plan for exploitation and dissemination of result

The plan for exploitation and dissemination of results as described in the DoA is largely still relevant and should be achievable. Even if the pandemic restricts the opportunities for in-person conferences these events are likely to continue online.

However, the pandemic has reduced the opportunities for in person outreach/engagement with the public (B2.4.1) with activities such as school visits, open days and science fairs being impossible. Currently, national restrictions and institutional policies still make these things impossible. It is not yet certain whether this will remain the case for the duration of i-CONN.

Conference Presentations:

Harald Waxenecker: Presentation [accepted] “El mercado público-privado de contrataciones: una cuestión de poder y riqueza” [Public procurement: a question of power and wealth] in the Conference “Confrontando las desigualdades sociales: Perspectivas sobre riquezas y poder” [Confronting social inequalities: perspectives about wealth and power], organized by CALAS (Centro Maria Sibylla Merian de Estudios Latinoamericanos Avanzados) in Quito, Ecuador. Postponed to March, 2022 <http://calas.lat/es/convocatorias/plataforma-para-el-diálogo-la-des-regulación-de-la-riqueza-en-américa-latina-un-nuevo>

Harald Waxenecker: Presentation [accepted] “Economía de Captura en Guatemala: desigualdad, excedentes y poder” [Capture economy in Guatemala: inequalities, profits and power] in the Conference “IX. Congreso Centroamericano de Ciencias Políticas” [IX. Central American Congress of Political Science] in El Salvador, September 8 – 10th, 2021

Mel Guirro: Presentation: EGU May 2021: Analysis of geometric relationships of bedrock and alluvial channels: a comparison between rivers from the Scottish Highlands and San Gabriel Mountains (USA) Mel O. Guirro, Rebecca A. Hodge, Fiona Clubb, and Laura Turnbull

Yanhua Shi: Poster presentation: “A network approach to action situations governing social-ecological systems: a case study of the Indonesian palm oil industry”, organized by EUSN 2021 (5th European Conference on Social Networks). Naples, September 6-10th, 2021 <http://www.eusn2021.unina.it/>

Yanhua Shi: Presentation [accepted] “Comparing two network approaches of social network analysis and network of action situation in a global environmental governance context “, organized by the New Institutional Economics (NIE) workshop in Potsdam at the Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB). Postponed to December 13-14th, 2021, in Potsdam.

3. Update of the data management plan (if applicable)

As promised in the DoA (B3.2.7) the [Data Management Plan](#) was revisited in the first six months of the action. The new DMP is more detailed and the new version was uploaded to (Deliverable D7.1). The DMP is an evolving document and will be reassessed as required. The DMP will be formally reassessed at the first Management Board meeting in 2022.

4. Follow-up of recommendations and comments from previous review(s) (if applicable)

The Project Officer met with privately with the i-CONN ESRs on Zoom in June 2021. This meeting replaced the meeting between the Project Officer and the ESRs that would normally have been part of the Interim Review meeting during Month 14.

The Project Officer identified three issues that needed following up:

- *Some ESRs were wondering about the use of RTN funds, especially unused funds during the Pandemic I have explained how this budget category works and the costs covered by this budget category. I believe I have answered most of their questions, however it might be useful to send them a quick message to explain how the budget category works and the way you have decided to handle this budget category in this project.*

Response: The ESRs had a talk from the Project Manager at our Kick-Off meeting about the budget but we recognise that at that time the information seemed academic to them. Since then, the Project Manager has had email exchanges with several of them about specific issues and the ESR representative raised some of these issues at our Supervisory Board meeting in March. The information shared with them at the kick-off meeting has always been available on our website but we reminded them about this resource. To make sure that we covered any additional issues that they had, the Project Manager gave a talk on July 2nd, 2021, entitled “ITN Finance for ESRs” via Zoom that included the opportunity for questions. A recording of this talk is available to the ESRs.

- *With the pandemic consequence, it might be useful to have a few meetings with the ESR/supervisor(s) once or twice a year to discuss with more details the CDP and assess whether some adjustments are needed.*

Response: The ESRs have all revisited their Career Development Plans. These were discussed by the Training Board on November 12th, 2021.

- *Personal situation regarding Selim Haj Ali: he has reported to have started his contract in September (due to visa issues) while he has been enrolled in a PhD in June. Based on the information received, my understating is that he started working on the project in June assuming that later payments would follow, but since the employment contract started in September, no payments were given to this ESR for the work he has done during these three months. May I kindly ask you investigate a bit further the matter with Selim's host institution and provide mor clarifications in this respect?*

Response: The Project Manager talked to Selim to ensure that he is happy with the situation at Jacobs. He would have started at Jacobs University earlier in summer 2020 if the situation had been normal, but because of the pandemic he couldn't organise a visa. As a non-EU national Jacobs would not issue him an employment contract until he could arrive in Germany. They can't make back payments of salary where there was no contract. Selim has a 36 month contract that started on September 1st, 2020. Selim's supervisor organised Selim's PhD registration before he realised that Jacobs University would not issue an employment contract. Selim still has a 36 month contract so he isn't losing any salary. Many of our ESRs started preparatory reading or holding meetings with their supervisor before their contracts started out of choice. Selim is happy with the situation and understands that there were legal reasons why Jacobs could not issue a contract with an earlier start date. It is unfortunate that there is not equality between the ESRs because of different nationalities and legal situations. Selim's fellow ESR at Jacobs was able to start earlier because she is an EU citizen and Durham University was able to issue employment contracts before our ESRs were in the UK, which none of the other Beneficiaries was able to do. The ESRs are very aware of these disparities but they reflect national rules or institutional procedures.

After the Interim Review Meeting, we were asked to provide more evidence of the eligibility of ESR 11, Christodoulos Karittevlis, who is a Cypriot employed as an ESR in Cyprus. Chris studied in the Netherlands from September 2017 – May 2020 inclusive for an MSc in Biomedical Engineering in Delft. This period included an internship and time spent preparing his thesis. During the final nine months he also had a part-time job in a Dutch company. Therefore, he lived in the Netherlands for 33 of the 36 months before starting employment as an ESR.

5. Deviations from Annex 1 and Annex 2 (if applicable)

Deviations from the DoA occurred in five areas:

- i) Delay to Deliverable (and associated milestone) Due Dates.
 - We requested, and were granted, an extension to the due dates of deliverables D1.1, D2.1 and D3.1 and D4.5.

- Deliverable D1.1 was delayed in order to expand the scope of the Deliverable and extend the work to the whole network. Not only was the Deliverable met but a publication was generated for the work.
- D2.1 was delayed as a recognition of the restrictions imposed on the leader of WP2 because of the pandemic. This deliverable has now been submitted.
- D4.5, the Datathon was delayed in order to maximise the changes of organising it as an in-person meeting. This was successful and 14 ESRs attended the Datathon in late September 2021.
- D3.1 This deliverable was delayed as the ESRs had been engaged in preparing contributions for D2.1. the involvement of so many ESRs in D2.1 had not been originally envisaged. Additionally, D3.1 is being informed by the outcome of the Datathon which was delayed. We are on track to deliver D3.1 by the end of November.

ii) Recruitment

The impact of the pandemic meant that the start date for some ESRs was delayed beyond the original planned date of 1st June 2019. This reflected the inability of ESRs to travel to their host country. Most i-CONN Beneficiaries have national rules that prohibit the award of contracts to non-national employees who have not arrived in the country. Fortunately, all ESRs were either able to work from the home country (in the case of the ESRs at Durham) or managed to travel and take up their contracts by the end of September 2020 so all ESRs have a full 36 month contract.

iii) Impact of the pandemic on training

The pandemic resulted in the planned training courses and workshops becoming online events. All events and course have still been delivered. To mitigate “Zoom fatigue” some events/activities were spread over a longer period than first planned. A positive outcome has been the launch of the i-CONN seminar series. This has increased accessibility with attendees at seminars watching from outside Europe. Ten seminars have been delivered.

iv) Changes to secondments

The delayed recruitment for some ESRs caused an associated shift in their secondment timetable. Additionally, the pandemic impacted on the planned secondments, with ESRs unable to travel either because they were not allowed to travel from their home institution or because the institution/country of the secondment host could not welcome. The secondment situation was discussed by the TB and it was agreed that it would not be appropriate to delay all secondments until the pandemic restrictions were lifted. Some of the secondments were more appropriate in the early stage of an ESR’s employment and it would leave a heavy secondment burden on the later stages of the ESRs contract if they were all delayed. It was decided that secondments should be delivered online or at least started online with the hope of a follow-up visit later in the

project. All secondment changes were discussed and approved by the training board and then agreed by the Supervisory Board before being discussed with the Project Officer.

There is a chart illustrating the timetable for the secondments including describing completed secondments as hybrid, online or in-person attached in Appendix 1

The pandemic has also undermined the chance to interact with the public in-person. Activities such as open days, science fairs and schools' visits have all been impossible and continue to be limited, if not still impossible, by both institutional and national regulations. This will continue for at least the short term and has the potential to be an issue for the duration of i-CONN.

Our outreach and engagement activities will largely take place online until in-person opportunities become viable.

v) Beneficiary Changes

- a) In the first version of the Grant Agreement, The UK Environment Agency was a Beneficiary to i-CONN and the University of Groningen was a project partner.

The Environment Agency (originally Beneficiary 7) implemented a recruitment freeze due to the political situation in the UK. They were therefore unable to recruit and employ an ESR with the consequence that they were no longer able to be a beneficiary of the i-CONN network. We therefore requested an amendment to our Grant Agreement, adding Groningen University as a new beneficiary in place of the Environment Agency and terminating the Environment Agency as a beneficiary. To match the expertise of our network as closely as possible with the ESR positions, we proposed to have ESR14 (originally Durham led) hosted at Groningen and proposed to have ESR 15 (originally EA led) at Durham University (closely connected to the Environment Agency).

No work was undertaken by the terminating beneficiary because the termination occurred before the recruitment of the ESRs.

The terminating beneficiary, the Environment Agency, continues to contribute to the i-CONN network as a partner organisation and as such hosts secondments and co-supervises ESR projects.

The overall objectives and expected results remain consistent with the original proposal.

- b) Louise Bracken, WP6 leader, moved from Durham University to Northumbria University on 1st August 2021. Bracken wished to remain part of i-CONN and to continue to supervise ESR15. Consequently, the Supervisory Board approved the addition of Northumbria University as an i-CONN Partner. Northumbria University is physically located close to Durham University and it is straightforward for

Bracken to remain closely involved with ESR15 who remains at Durham University. To comply with Durham University rules, Laura Turnbull-Lloyd became the lead supervisor for ESR15.

5.1 Tasks

Apart from the deviations discussed in the previous section our tasks and objectives are either are either fully implemented or on schedule.

6 Ethics

The i-CONN Ethics statement is attached as Appendix 2.

This document does not need updating at this stage. Most ESRs are using secondary datasets that are publicly available.

In the case of the data being used/generated by two of our ESRs further clarifications have been received:

ESR 4 Harald Waxenecker

The research focus of this ESR project is on public procurement (contracting), interlocking directorates (private companies) and business-state connections (decision-making), applying different social network approaches. Therefore, the datasets include personal data (names) of businessmen and businesswomen linked to company boards and public entities. The data is publicly available and can be freely used for the research project.

This information is essential and relevant to study the state-business-connectivity and the clientelist networks that undermine fair economic competition and transparent and democratic decision-making. The personal information about surnames and gender is also relevant to studying the underlying kinship relationships. In compliance with the data protection rules, personal information will be pseudonymised.

ESR 11 Christodoulos Karittevlis

In Period 1 we have used data from a common open database derived from sleep experiments performed in Japan. We (AAISCS) have a material transfer agreement with BSI RIKEN which includes abiding by the ethics committee of BSI RIKEN regulations related to the performance of the experiments and the additional ones stipulating anonymization before transfer to Cyprus. This analysis is currently performed entirely within AAISCS.

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Appendix One

i-CONN Secondment Chart, including the format of completed secondments.

Mode of completed secondments:

Yellow, secondment in person

Purple, completed virtually

Green: h = hybrid (completed, some days each week spent at host), * = started virtually with the plan to visit later in the grant period

J = Jacobs, AI = AAISCS, B = BOKU, D = Durham, EC = European University Cyprus, AM = Aix-Marseille, G = Groningen, EA = Environment Agency, V = University of Vienna, I = IIASA, Ma = Masaryk, Mo = MODUL

Mon th No.	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
	O 2020	N	D	J 2021	F	M	A	M	J	J	A	S	O	N	D	J 2022	F	M	A	M	J	J	A	S	O	N	D	J 2023	F
1 ST				AI v	AI v	AI v				EC x		B x	B x	B x		D x	D x	D	AM	AM									
2 VV												EC x	EC x			D x	D x	D	AM	AM	AM								
3 SHA								AI v	EC v					AM	AM	AM					D								
4 HW																				G				EC				Mo	Mo
5 VL													AI h			EC	EC	EC	J	J	J					EA	EA		
6 MG												V x	V x	V v	V v			AI	AI										
7 MP			AI x	AI x	AI x											D	D	D	D		AI	AI							
8 SR								EC v						I	I			V	V										
9 YS															EA		B	B						EC	EC				
10 JP																						I	I		B	B	B		
11 CK		EC h						J v	EC h						D	D	D					EC	EC						
12 MD		I v	I v	I v										J				EA	EA					EC	EC				
13 DP	G *	G	G								AI *	AI	AI								J	J	J						
14 MM											Ma h			EA	EA	EA													
15 JC								EA *	EA	EA	EA							B	B	B	B								

6. Ethics Issues

6.1 Describe how the proposal meets the national legal and ethics requirements of the country or countries where the tasks raising ethics issues are to be carried out

6.1.1 General comments for the bulk of the data

The partners in the i-CONN network are fully committed to the research as described and will comply with appropriate European, national and local ethical requirements. We have identified that this project should be subject to a full Research Ethics Committee review as it involves human participants and personal data. If funded a full review will be undertaken before the research begins. The European Charter for Researchers will be used to guide research overall, and we will employ the appropriate ethical principles of impartiality, reliability, integrity and responsibility as described therein as well as in the range of disciplinary codes of practices and requirements laid down by each of our institutions. We will also ensure we follow current best practice by incorporating a training session on research integrity in the Kick-off meeting of the project.

The ethics issues associated with most of the data to be analysed are limited because these involve physical measurements (e.g. galaxy formation in the universe, land and water properties of locations on Earth, ecosystem measurements). Standard practices of informed consent for access to locations to collect these data will be followed, and non-invasive techniques will be employed wherever possible. The research methods will outline how sites should be restored following any measurements, if appropriate. All data analysis will be carried out in institutions within the EU countries so there will be no involvement of third countries.

However, some outcomes of the research have the potential to affect directly the well-being of local communities, for example in looking at the impacts of resilience in landscapes, or the potential for flood mitigation. In these cases, our transdisciplinary approach means that we will include local communities from the outset in a Participatory Action Research (PAR) framework. This inclusion means that local people will have the ability to guide research and its outcomes, and will be able to give informed consent about the data collected and their use.

6.1.2 General comments for the Human data

The conduct of researchers and the transmission of information involves a wide range of ethical considerations with implications for data analysis, user-engagement, research output and data archiving. The key ethical issues are voluntary informed consent, the confidentiality of information provided by participants and the anonymity of participants.

Research aims, objectives, methodology and confidentiality will be explained to the participants at all stages of the research and assent gained before recording. Respondents will not be obliged to take part and will be free to withdraw involvement at any time without consequence. We will take care to ensure that participants and respondents are comfortable speaking to the researchers by: i) ensuring confidentiality; ii) using settings where the participants are comfortable; and iii) conducting research only when relations of trust have been developed.

Participants will be informed of the potential impact of the research and the data-archiving process and their written (or otherwise recorded) informed consent will be sought for data sharing and archiving. No data will be acquired through deception or misrepresentation and all participants will be informed of the extent to which anonymity and confidentiality can be assured in publication and dissemination and in any data re-use. We are committed to FAIR principles and will ensure that no data are stored in a way that could allow individuals to be identified.

There will be no new experiments with humans planned specifically for the research of this ITN project, but data from existing and ongoing electroencephalography (EEG) and magnetoencephalography (MEG), neuroimaging (mainly functional Magnetic Resonance Imaging (fMRI)) and structural imaging (mainly MRI and Diffusion Tensor Imaging (DTI)) will be used in the

work of some of the ESRs. Work that involves collection of socio-economic data will follow standard practices of informed consent, again, wherever possible using a PAR framework. Table 6.1 lists the relevant Ethics Committee that will approve any related work for each partner.

Table 6.1 List of the relevant Ethics committees for each i-CONN partner

Partner	Ethics Committee providing approval
UDur	Department of Geography Durham Ethics subcommittee reporting to Durham University Ethics Committee (https://www.dur.ac.uk/research.office/local/research.governance/ethics.committee/)
JU	Jacobs University Office for Academic & Public Affairs
AAISCS	Cyprus National Bioethics Committee
EUC	Cyprus National Bioethics Committee
UNIVIE	Ethics Committee of the University of Vienna (http://ethikkommission.univie.ac.at/en/mission-statement/)
BOKU	BOKU Ethikplattform (http://www.boku.ac.at/en/ethikplattform/)
MU	Research Ethics Committee of Masaryk University
AMU	Comité de Protection des Personnes Sud Méditerranée
MUV	MODUL University Vienna, Institutional Review Board
USFD	University of Sheffield Research Ethics Committee
EnvA	Committee on Standards in Public Life
IIASA	Review carried out by <i>ad hoc</i> committee
UMD	University of Maryland Internal Review Board (IRB) (http://www.umresearch.umd.edu/RCO/New/index.html)

Partners will submit their research methods to their local ethics committees at the outset of the project, and update them as appropriate as research progresses. Copies of official documents authorizing each piece of research will be passed to the i-CONN network coordinator before the ESRs commence employment in month 8.

Some of the information reported in the following sections have been identified in the context of previous projects SmokeFreeBrain (agreement number 681120 [Horizon 2020] – from November 2015 until October 2018) and ARMOR (agreement number 287720 [FP7] – from October 2011 to April 2015). In these two projects the human data collection and human neuroimaging data analysis performed was similar to the one planned for i-CONN. While in the ARMOR and SmokeFreeBrain projects the emphasis was more on the localization of generators, in i-CONN the emphasis will be on connectivity (with the localization of generators a pre-requisite for connectivity analysis in the source space). We note that in the other two projects the recording of human non-invasive neuroimaging data and their analysis was more intensive and central to the research than in the i-CONN project. We describe below the properties of the data to be used in the i-CONN project.

A) Organization and research aspects:

- The organizations where the experiments are performed and the organizations acting as primary hosts for the ESRs fully and freely consent to the research and the participation of their members in the research activities.
- The ESRs and their supervisors will be jointly involved in the planning of each experiment and analysis and they fully and freely agree to carry out their respective tasks as jointly agreed.

B) Subject and privacy aspects for existing data:

- All human data used in these ITN projects are anonymized
- All subjects gave their informed consent for the experiments and were informed that their data, after anonymization would have been used for further analysis.
- All data are from experiments approved by the relevant local ethics committee
- All data are from experiments performed according to the local, national and international legislation of the laboratory where the experiments were performed with

explicit approval by the relevant local/national ethics committees and performed in accordance to international conventions such as the Helsinki declaration.

C) Subject and privacy aspects for new data:

- All new human data will be used for analysis in these ITN projects after anonymization
- All subjects will give their informed consent for the experiments and will be informed that their data, after anonymization would have been used for further analysis and specifically that they might be used by the i-CONN ITN projects.
- Any new experiments will be approved by the relevant local ethics committee:
 - Either as part of a wider ethics application submitted on behalf of a parent project and explicitly mentioning the use of the data after anonymization by the i-CONN projects
 - Or, as a separate standalone application to the ethics committee for the i-CONN projects.
- All new experiments will be subject to the approval of the local/national ethics committee and will be performed according to their stipulation and in accordance to any other local, national and international legislation of the laboratory where the experiments will be performed and in accordance to international conventions like the Helsinki declaration and EU Charter of Fundamental Rights.
- Already starting from the negotiation phase, the consortium will ensure that all the documents necessary for ethical clearance are collected including, but not limited to, copies of relevant ethics approvals, informed consent forms, information sheets and any other material required. These documents will be kept and available for inspection by the coordinator of the project team.

D) Personal data storage and sharing:

The following sections list the most relevant legal frameworks at international level in matters of relevance for i-CONN in particular regarding personal data management, privacy and security and informed consent.

- Directive 95/46/EC on the protection of individuals with regard to the processing of personal data and on the free movement of such data
- Directive 2002/58/EC concerning the processing of personal data and the protection of privacy in the electronic communications sector (Directive on privacy and electronic communications)

These directives give indications about ethical principles for medical research involving human subject and data processing. The privacy principles are summarized as follows:

- The collection and processing of personal data shall neither intrude on the data subjects' privacy nor interfere with their autonomy and integrity.
- Personal data shall be collected and processed only after explicit consent
- Personal data shall be collected for specified, lawful and legitimate purposes.
- The collection and processing of personal data shall be limited to the minimum necessary for achieving the specific purpose. This includes that personal data shall be retained only for the time necessary to achieve the specific purpose.
- The disclosure of personal data to third parties shall be restricted and only occur upon certain conditions.
- Personal data shall be accurate, relevant, and complete with respect to the purposes for which they are collected and processed.

- The data subject shall be able to check and influence the processing of his/her personal data.
- The processing of personal data, which are particularly sensitive for the data subject, shall be subject to more stringent protection measures than other personal data.
- Personal data shall be processed in a way that guarantees a level of security appropriate to the risks presented by the processing and the nature of the data.

In relation to security of personal data processing, at the EU level the main reference is art. 17 Directive 95/46/EC and, in particular the first two items, i.e.:

- “1. Member States shall provide that the controller must implement appropriate technical and organizational measures to protect personal data against accidental or unlawful destruction or accidental loss, alteration, unauthorized disclosure or access, in particular where the processing involves the transmission of data over a network, and against all other unlawful forms of processing. Having regard to the state of the art and the cost of their implementation, such measures shall ensure a level of security appropriate to the risks represented *by the processing and the nature of the data to be protected*.
- 2. The Member States shall provide that the controller must, where processing is carried out on his/her behalf, choose a processor providing sufficient guarantees in respect of the technical security measures and organizational measures governing the processing to be carried out, and must ensure compliance with those measures. (...)”.

On 25 January 2012 the European Commission proposed a comprehensive reform of the EU's 1995 data protection rules to strengthen online privacy rights and boost Europe's digital economy. The major novelty of the proposed regulation, as reported in the communication are:

- A single set of rules on data protection, valid across the EU, instead of the current obligation of all companies to notify all data protection.
- Provision for increased responsibility and accountability for those processing personal data.
- Organizations will only have to deal with a single national data protection authority in the EU country where they have their main establishment. Likewise, people can refer to the data protection authority in their country, even when their data is processed by a company based outside the EU.
- Wherever consent is required for data to be processed, it is clarified that it has to be given explicitly, rather than assumed.
- People will have easier access to their own data and be able to transfer personal data from one service provider to another more easily (right to data portability). This will improve competition among services. A ‘right to be forgotten’ will help people better manage data protection risks online: people will be able to delete their data if there are no legitimate grounds for retaining it.
- EU rules must apply if personal data is handled abroad by companies that are active in the EU market and offer their services to EU citizens.
- Independent national data protection authorities will be strengthened so they can better enforce the EU rules at home. They will be empowered to fine companies that violate EU data protection rules.

Lastly, with regard to informed consent, this must be considered a prerequisite and essential to any treatment, even more when the processing modalities through which it is carried on result in the creation of risks and potential problems to the security and integrity of the data itself. The consent is the main instrument through which the principle of self-determination is expressed (Directive 95/46/EC).

From a technical point of view, consent to the processing of health data must generally be made in writing (Directive 95/46/EC art .2). This formality, even if it is easily manageable through traditional paper-based interactions at the time of the first contact between the patient and the health care body that provides the health service, may, however, be a critical point to solve if not properly managed also from a digital point of view.

6.2 Explain in detail how the consortium intends to address the ethics issues raised in the Ethics Issues table from part A, in particular as regards: research objectives; methodology; and potential impact of the research

The project has no particular issues to address since the main emphasis is on training ESRs on a wide range of connectivity methods, spanning a range of domains. There are no activities or results raising security concerns and there will be no use of background or results from “WU-classified information”. The results of the work could nevertheless be applied in many different areas and this could have significant impact on clinical populations and society at large. We therefore comment explicitly on such matters here.

- In the research **objectives** of the proposal there is no plan to study specifically clinical groups or vulnerable populations, applications for defence or dual use of the results. However, like any other theoretical advance and implementation of data mining techniques, the methods developed in the i-CONN project could be used in the future for clinical application and for identifying early vulnerable members of society. In the project we will deal with this aspect in two ways:
 - We will include in the training of ESRs possible applications of the method that will advance positive applications of the method to clinical practice (e.g. monitoring therapies, finding biomarkers of disease or prodromes of disease).
 - We will also include in the training of ESRs the ethical issues involved in possible misuse of scientific advances in general and specifically of the methods that ESRs will become familiar with and actually help advance further.
- The research **methodology** will not involve clinical trials, and any use of existing data will be after all data privacy matters have been dealt with as described in detail under section 6.1.2.
- The intended potential **impact** of the research is for a positive improvement of the quality of life:
 - In the bulk of the data the effort will be to avoid environmental damage, wrong economic and political decisions and planning of city and rural land development (through connectivity analysis that will result in improvement of understanding of complex interdependencies within complex systems).
 - In terms of clinical and health related applications the research is aimed at understanding better not only aspects affecting the health of individuals but also for groups and the earth population at large (e.g. through development of new and improvement of existing connectivity analysis for the spreading of disease).

Again there is always a risk that the development of methods intended for the benevolent applications to be hijacked for malevolent use. The consortium recognize this unavoidable risk and the response is as above to provide training to the ESRs alerting them to possible misuses so that they can identify any such cases early so they can be stopped before they become a threat.

6.3 Gender issues

The i-CONN network is highly aware of gender-equality issues, and has addressed them at all stages of the development of the team. The team has an excellent gender balance, with the network

coordinator and half of the WP leaders being female. We have also made efforts to include a balance of different career stages. Explicit training for network members in avoiding gender bias will be included in a preliminary online recruitment meeting that will lead to the development of a policy guide that will be used by each team member when recruiting the ESRs. This training will also be repeated at the Kick-off meeting for the benefit of ESRs.

In terms of the research, the policy guide will also be used to inform research methods and sampling approaches. Together with the experience of the project members and the practice of ethical approval for all parts of the research, this approach will ensure research carried out is unbiased and representative.