Universität Konstanz

CASCB
ANNUAL REPORT

2021

Centre for the Advanced Study of Collective Behaviour

FOREWORD

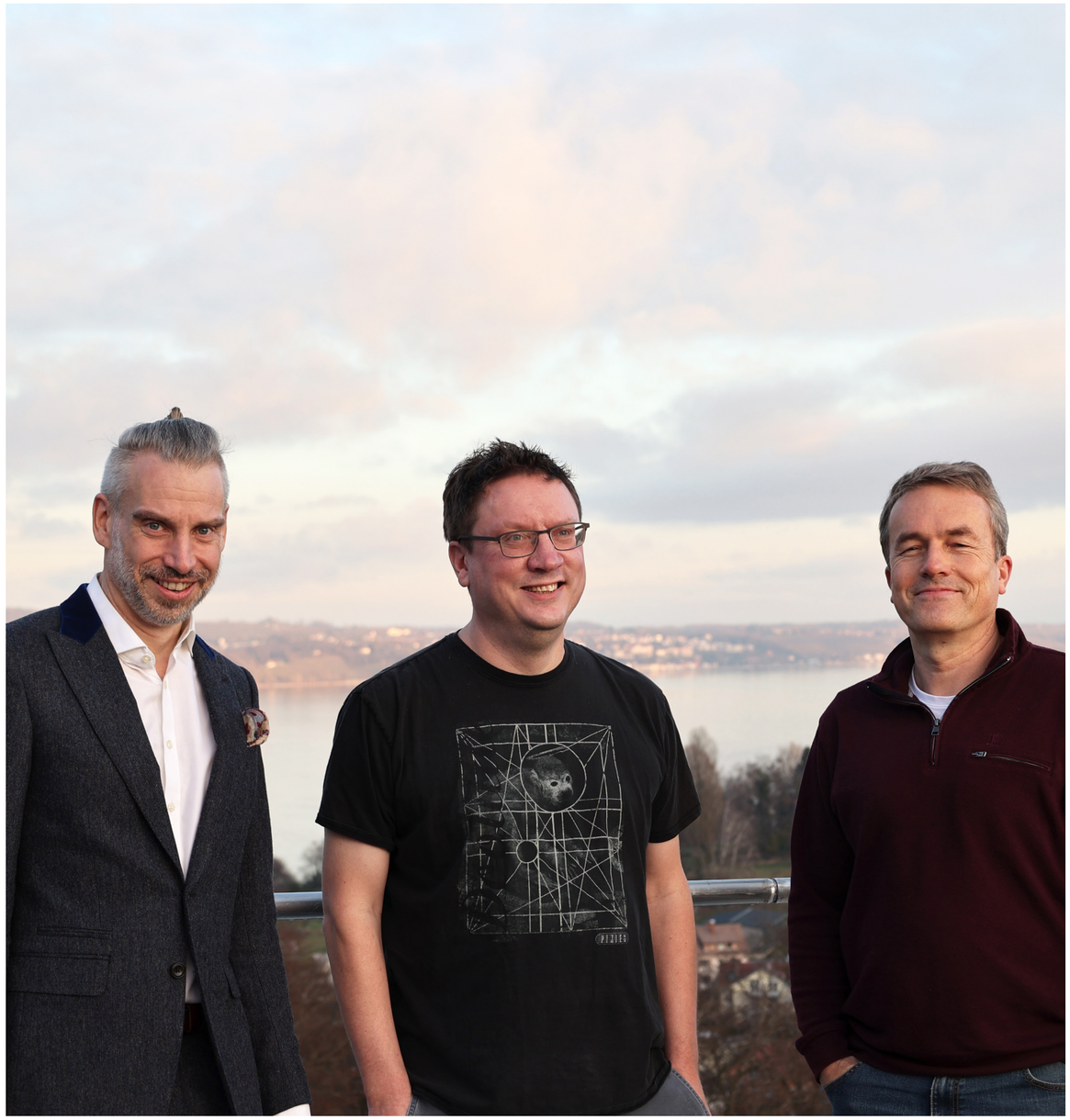
2021 is coming to an end and with it the third year of the Centre for the Advanced Study of Collective Behaviour. A year's end is always the time to reflect on what has happened as well as on our goals for the near and (more) distant future – even more so as we are now nearing the end of the first half of the seven-year funding period.

To get the elephant in the room out of that room, let us start with the bad: This year has been another year under the shadow of the pandemic, with a significant impact on our research and community. We were largely locked down at the beginning of the year, rendering real in-person community life and informal exchange, but also much of important lab and field work difficult to impossible. After a vaccination programme was rolled out here in the spring and early summer, there was a glimpse of hope for more of the old normal, despite existing projections that the pandemic is far from being over. The situation here in Germany is worse than ever before, with a fourth wave that has hit us with full force.

The crisis is too serious to use the euphemism that every crisis is an opportunity. However, we think it is important also to highlight the good during these difficult times. First of all, we are fully aware that despite being hit hard by the pandemic, we are still in a privileged situation, which holds true both in comparison across societies, but also within the society here. This is by no means meant to downplay any individual struggles that people are facing. At the same time, looking at how our wonderful community stood together and has adapted and coped with the situation also makes us proud of being part of that endeavour.
Our special thanks and acknowledgement go to the cluster office team and the early career researchers who have been affected most severely, but who have also been extremely creative regarding how to make the best of this exceptional situation. This includes the organization of a digital Spring Retreat, where it was predominantly the early career researchers who communicated their exciting research to the community with such zest and have inspired so much of the interdisciplinary exchange that we always envisioned. It included research that was creatively adjusted to target the pandemic rather than just being its victim, as crucial aspects of the pandemic, such as the perception of the costs and benefits of vaccination or the role of physical distancing to mental health, are all collective phenomena. Vaccination only works as a result of herd immunity, bringing collective behaviour to the forefront of pandemic response. Finally, there have been great solutions to how research can be (made) possible under pandemic conditions that will have sustainable benefits for the community at large.

Important milestones and a growing community

Despite this major obstacle, the year has had much to offer in terms of important milestones for our centre. One of the most important ones, and definitely the most visible, has been the opening of the Centre for Visual Computing of Collectives (VCC). The building, with a budget of € 30 million, was completed this year and provides world-class infrastructure over eight floors and with over 3,000 m^2 of dedicated research facilities. It has enabled the cluster community to grow even further: New junior group leaders have started to build up their labs and new early career researchers from all over the world have been integrated into existing groups. Even for those who are not directly accommodated there, the VCC provides a hub and vibrant meeting space for all of us – a home for the study of collective behaviour.



2021 has also been an important year for funding new projects. Most noteworthy, there has been the mid-term open call for large projects, where the cluster's Executive Board decided to fund 15 of the received proposals. Some projects are completely new, some of them are continuing core research from the 13 original starting projects that defined the beginning of the whole endeavour in 2019. This combination allows us to simultaneously further our existing strengths while also allowing us to identify novel important topics that are emerging across the various disciplines involved. These large projects are complemented by many small to medium-sized projects with which we support our community, aiming to facilitate low-threshold testing of new ideas or methods that may contribute to the big research areas of tomorrow. Alltogether, we have funded almost 100 projects since the cluster's setout and our funding continues to be extremely fruitful: In 2021, our research yielded 124 new publications in world-class scientific journals, including Science, Nature Communications, and PNAS.

Overall, this has been a challenging, but also a very fruitful year thanks to our amazing community. We have grown, and we have grown together, scientifically and personally. The most important task for the year and years to come will be to integrate our exciting results into a more encompassing theory of collective behaviour. From the evidence of what our members are capable of even under constraints, we are hopeful that this will be achieved. And for now, we are hopeful that this annual report can convey at least some of the joy and the gratefulness of being part of this collective that is so much more than the sum of its individuals.

CASCB co-speakers // Konstanz / December 2021

Wolfgang Gaissmaier **Iain Couzin** **Oliver Deussen**

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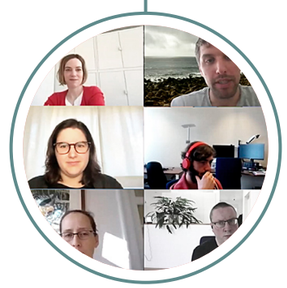
AT A GLANCE

RESEARCH



CULTURE OF COLLABORATION

PERSONNEL

Status quo of the cluster

Our starting point

- We aimed to create a global hotspot for the integrated study of collective behaviour across a wide range of species, including humans, and across scales of organization.
- We brought together researchers from biology, psychology, behavioural economics, sociology, physics and computer science.
- 13 large-scale, interdisciplinary starting projects enabled us to get up and running.

Three years later

- The move to the VCC is completed; our new building has become a hub for research and collaborations.
- The cluster's Executive Board approved funding of 15 large-scale projects that will run over the next 2-3 years. Together with 55 new, short-term, small and medium-sized projects in 2021, this amounts to a final count of 93 proposal submissions approved for cluster funding since 2019.
- 4 junior groups and 11 incoming employees joined in 2021.
- The adjacent infrastructure contributes to making Konstanz a global hub in the field of collective behaviour. Particularly worth highlighting are the development of the MPI AB, the participation of the Department for the Ecology of Animal Societies (Meg Crofoot) and a Humboldt Professorship.

Our goals for 2022 and beyond

- Synthesize findings towards a coherent picture of the underlying (theoretical) principles, mechanisms, drivers and ultimate consequences of collective behaviour across species and scales of observation.
- Identify and develop new lines of research and emerging topics within our growing community.
- Continue and intensify our engagement and scientific outreach in topics of global importance, such as public health, conservation and stewardship of social systems.
- Make use of our growing infrastructure, such as the Imaging Hangar in the VCC: Kick-off experiments include how environmental uncertainty shapes rats' foraging behaviour in large-scale environments and the study of movement patterns in larger scale locust swarms.

Look how we are further developing...

Staff Headcount

- 28 Academics
- 9 Global Cooperation Partners
- 19 Affiliate Members
- 12 PhDs
- 11 CASCB Doctoral Network
- 17 Early Career Researchers
- 8 Alumni
- 9 Group Leaders
- 6 Office Members

Collaboration

- 3 Conferences
- 3 Outreach Events
- 1 Research Retreats
- 9 Visiting Speakers
- 19 Research Seminars

Research

- 124 Publications
- 70 Funded Projects

Teaching

- 3 Uni Courses

Grants

- 1 Bees & Trees Foundation
- 1 BMBF
- 2 Emmy Noether
- 1 Research Fellowship of the Zukunftskolleg Konstanz
- 1 Elite Programme for Postdocs of the Baden-Württemberg Stiftung
- 1 Independent Research Grant from Zukunftskolleg
- 3 DFG grants

Awards

- 1 Fellow of the Gesellschaft für Informatik
- 1 Highly Cited Researchers
- 1 Awards from Centre for Research and Conservation BE
- 1 Award from Gordon and Betty Moore Foundation
- 1 Alexander von Humboldt Postdoctoral Fellow
- 2 Lehrpreis des Landes Baden-Württemberg
- 1 Gottfried Wilhelm Leibniz Prize
- 1 Best Paper Award from the IMPRS for Organismal Biology
- 1 Order of Merit of Baden-Württemberg

Moving to the VCC

Finally! In June 2021 we moved to the new Centre for Visual Computing of Collectives (VCC) at the University of Konstanz.

The VCC is an interdisciplinary research centre that focuses on collective animal and human behaviour and its underlying mechanisms.

The research building provides world-class infrastructure on eight floors with over 3,000 m^2 of research facilities. The Centre for the Advanced Study of Collective Behaviour is located on one of the floors. Several group leaders, postdocs, doctoral students and the office team are now working in the university's newest building.

Oliver Deussen, one of the cluster speakers, says: "With the VCC building the cluster now has a home, a central place for research and working as a real cluster. It allows us the necessary space to grow together, to share ideas to chat at our coffee machine. There are lots of labs and the Imaging Hangar to help us conduct our experiments. I am so happy that this has finally become reality!"

With a budget of € 30 million, the VCC houses cutting-edge facilities for the collection, exploration and subsequent analysis of collective behaviour data. At the heart of the VCC building is the Imaging Hangar.

Dr Danyal Bayaz, Finance Minister, officially handed over the new building to the University of Konstanz in October.

15 *Visit by the former Federal Minister of Education and Research Anja Karliczek*
16 *Mathias Günther gives an insight into the Imaging Hangar*
17 *Official opening ceremony of the building and handover of the keys by the State Minister of Finance Danyal Bayaz*
18/19 *Impressions of the work done in the VCC*


Collective Behaviour
Seminar Series
Winter Semester 2021/2022
Centre for the Advanced Study of Collective Behaviour

The Imaging Hangar

An excellent foundation for research on collective behaviour

The Imaging Hangar will interface large-scale collective biology and computer vision to create a globally unique key-facility for the new Centre for Visual Computing of Collectives (VCC).

The Imaging Hangar will accommodate one of the largest infrared motion capture arrays in existence. This allows us to precisely analyze the motion of individuals even as small as locusts on a sub-millimetre scale. Even in larger swarms with hundreds of animals we can accurately identify individuals. This, together with a visual camera array, will create effective synergies for investigating and teaching computer vision algorithms with which to observe collectives wherever conceivable. In addition, the Imaging Hangar will be further developed into a virtual environment. Already implemented for humans and used to study VR-influenced group behaviour in a large and well-controlled space, we are planning to transfer our approaches to a large number of species in order to create an immersive and reactive space for simulating natural habitats. A further goal is to investigate biological behaviour by applying the rules of collective behaviour to artificial individuals such as drones.

The Imaging Hangar is

- A reactive 3D environment covering 1,900 m^3 and equipped with a wide range of state-of-the-art technologies
- A facility for studying a broad spectrum of species and a platform for researchers from around the world
- An opportunity to gain deeper insights into the science behind collectives

"I'm proud to be developing this fascinating facility together with an interdisciplinary team of scientists. And I will do my best to turn their ideas into reality!"

Mathias Günther
Imaging Hangar Facility Manager

"The research group I'm building here aims to investigate basic principles underlying rats' foraging decisions in large-scale dynamic environments that mimic natural habitats. Using patch foraging as a quintessential behavioural paradigm and a combination of high-throughput continuous video tracking and quantitative modelling approaches, we aim to elucidate how foraging strategies are updated in a changing social and physical world."

Ahmed El Hady
Postdoc conducting the first experiment in the Imaging Hangar

March 2015

Initial idea

2018

Laying of the foundation stone

March 2021

Imaging Hangar proposal approved by the German Research Foundation

October 2021

Official inauguration of the building

2022

Installation of technical equipment and first experiments

“The idea behind the Imaging Hangar was that there is a lot of work on a small scale and in the field, but nothing that connects the two. This lab would provide the only space in the world where such studies can be undertaken.”

Iain Couzin
CASCB co-speaker and Imaging Hangar initiator

Specifications

- → 12 × 12 × 6 m fully insect-proof experimental space
- → Fully air-conditioned
- → Up to 10,000 Lux in daylight quality
- → Full spatial coverage of an IR motion capture system to track objects on a sub-millimetre scale
- → Multi-camera array to observe animals as small as locusts within the full floor space
- → VR headsets for human experiments
- → Tobii eye-tracking
- → Bitcraze drone swarm
- → Whatever you can dream of…

Our exciting research results
Selection from 2021

Principles and mechanisms of swarm behaviour

Evidence of fundamental geometric principles across taxa and ecological contexts: When presented with spatially distributed options, fruit flies, desert locusts and larval zebrafish all exhibit the same principle of bifurcation in their collective decision-making. From averaging vectorial information before approaching abrupt "critical" transitions, they spontaneously switch to excluding one among the remaining options. This process repeats until only one option – the one ultimately selected – remains (Sridhar et al. 2021, *Proceedings of the National Academy of Sciences*).

Group-level coordination without communication: Individual sensing and decision-making enable ant collectives to form complex adaptable structures (Lutz et al. 2021, *Proceedings of the National Academy of Sciences*).

Manipulation of individual genes in zebrafish larvae changes simple behavioural responses to visual stimuli and thus affects their collective behaviour (Harpaz et al. 2021, *Science Advances*).

Insights into social systems, group living and social decision-making

Immigration is revealed as a powerful driver of cultural change in animal groups that makes them more efficient and could help them adapt to rapidly changing environments (Chimento et al. 2021, *Current Biology*).

Wild birds use social knowledge to avoid being deceived by conspecifics (Cunha & Griesser 2021, *Science Advances*).

High-resolution tracking data together with simulations of wild baboon movement demonstrate that collective movement in a highly despotic social species is driven by a shared decision-making process, in which all individuals modulate their gait and movement pauses to maintain cohesion with the group (Harel et al. 2021, *Proceedings of the Royal Society B*).

On the global relevance of the study of collective behaviour

Human presence disturbs the social networks in social species such as giraffes (Bond et al. 2021, *Journal of Animal Ecology*), in which sociability is linked to higher survival in adult females (Bond et al. 2021, *Proceedings of the Royal Society B*).

As part of an interdisciplinary global team, CASCB researchers make the case that the study of collective behaviour must rise to a "crisis discipline" just as medicine, conservation and climate science have, with a focus on providing actionable insight to policymakers and regulators for the stewardship of social systems (Bak-Coleman et al. 2021, *Proceedings of the National Academy of Sciences*).

Collective behaviour and public health

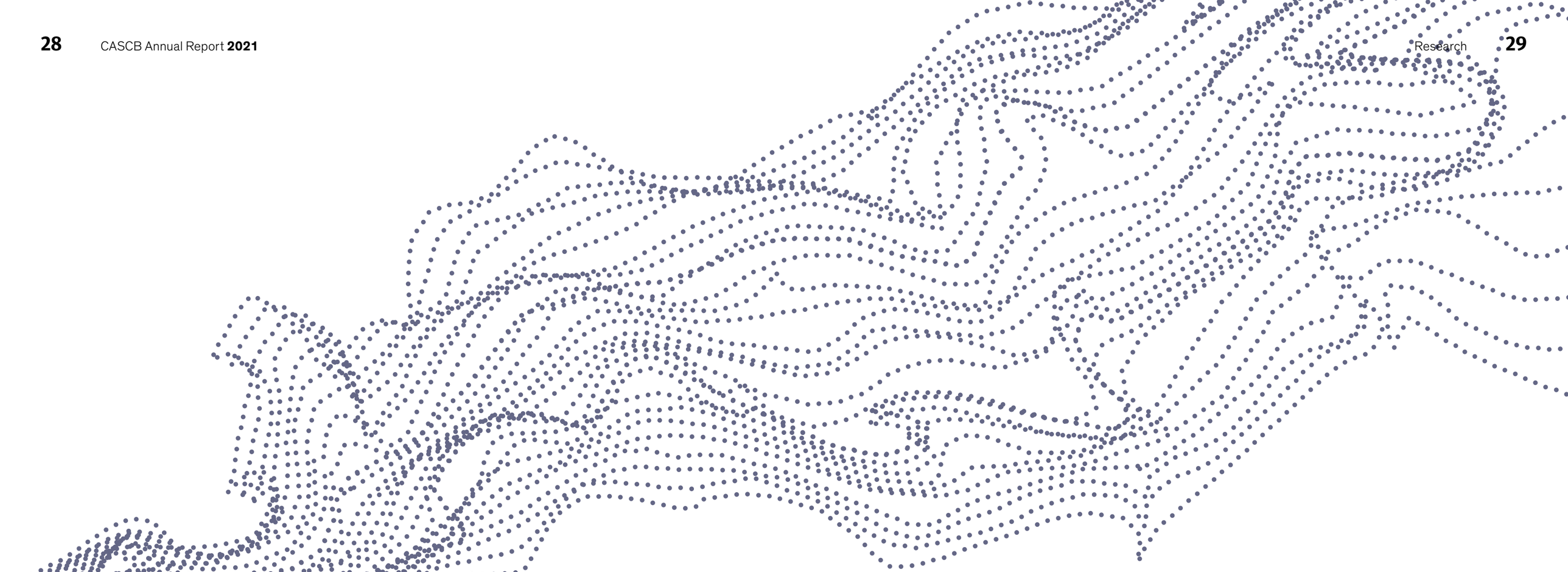
The attention to scientific facts and the likelihood of sharing them can be increased if those facts are communicated in a more understandable manner, such as by using visual displays (Giese et al. 2021, *Vaccine*).

Development of groundbreaking tools and technologies to study collective behaviour across multiple scales

Development of TRex, a user-friendly tracking system with markerless identification and 2D estimation of posture and visual fields of hundreds of individuals (Walter and Couzin 2021, *eLife*).

SpatialRugs, a technique developed by CASCB researchers and geared towards collective movement data sets, can be applied to reintroduce spatial positions by applying 2D colourmaps to determine object locations and enable users to follow spatio-temporal developments even in non-spatial representations (Buchmüller et al. 2021, *Computers and Graphics*).

RESEARCH →



A

How does information, behaviour and physiological state spread in collectives?

B

What are the consequences for collective outcomes?

C

How to analyze, predict and model collective behaviour?

Cornerstones of Research

Our goal is to uncover the fundamental principles that underlie collective behaviour – in a range of organisms and across scales of organization – and to translate this knowledge into real-world solutions that will bring about positive impact worldwide. Our scholars from biology, physics, psychology, sociology, economics, computer science and maths step beyond the comfort zones of their systems in order to work together to pursue this common goal.

Our approach is to refract collective behaviour research through the prism of three structural elements:

- Studying the individual in the collective (Area A)
- How this behaviour aggregates in the collective (Area B)
- Using theory-based empirical studies that exploit high-tech computational methods (Area C)

To date, 93 projects have succesfully been awarded grants. Each proposes an innovative, interdisciplinary concept that illuminates the path to our research goal. Projects are financed via one of three funding lines: small (10K), medium (80K) and large (<80 k) grants.

Area A

How birds learn

Mechanisms underlying heterogeneity in social learning between individuals and groups

Biologists Lucy Aplin, Michael Chimento and Sonja Wild are interested in the mechanisms underlying social learning processes and how they drive cultural outcomes. They use the bird species great tits (Parus major) in the wild and in captivity with temporarily retained wild-caught individuals as an experimental model system. Their aim is to test what learning rules individuals employ, whether these rules vary between individuals, according to context, life stage and in response to changes in the environment (physical or social), and how such individual decision-making affects emergent behaviour at group level.

→ MECHANISMS UNDERLYING HETEROGENEITY IN SOCIAL LEARNING BETWEEN INDIVIDUALS AND GROUPS

Could you please give us a deeper insight into your methodology and experiments?

Lucy Aplin Our manipulative experiments modify available food resources, the information available to individuals about food resources and social structure itself, during ontogeny and adulthood. The methodology relies on automated data collection. Birds are tagged with lightweight RFID microchips in the wild (<0.1g) and with QR barcodes (1g) in captivity to track behaviours around set locations.

"We have taken on the challenge of investigating the ontogeny of social learning strategies of great tits during transition to independence, which has not been done before due to the difficulty of tracking young birds after fledging."

But how can you explore the social learning exactly?

Aplin The microchips are paired with automated cognitive puzzles, where birds need to push a sliding door either to the right or left to get a food reward. These puzzles are used on both captive and free-ranging tits in social learning diffusion experiments. We then use a combination of network-based diffusion analysis and experience-weighted attraction modelling to identify learning and decision-making mechanisms and track how they trade-off personal experience with social influence.

What is novel about your project?

Aplin Previous research on social learning has generally assumed that social learning biases are evolved strategies that are relatively fixed on both individual as well as population level. We challenge these assumptions by using automated tracking data in individual-based learning models to understand the factors that influence individual decision-making processes and their consequences for behaviour on group level. Furthermore, we have taken on the challenge of investigating the ontogeny of social learning strategies of great tits during transition to independence, which has not been done before due to the difficulty of tracking young birds after fledging.

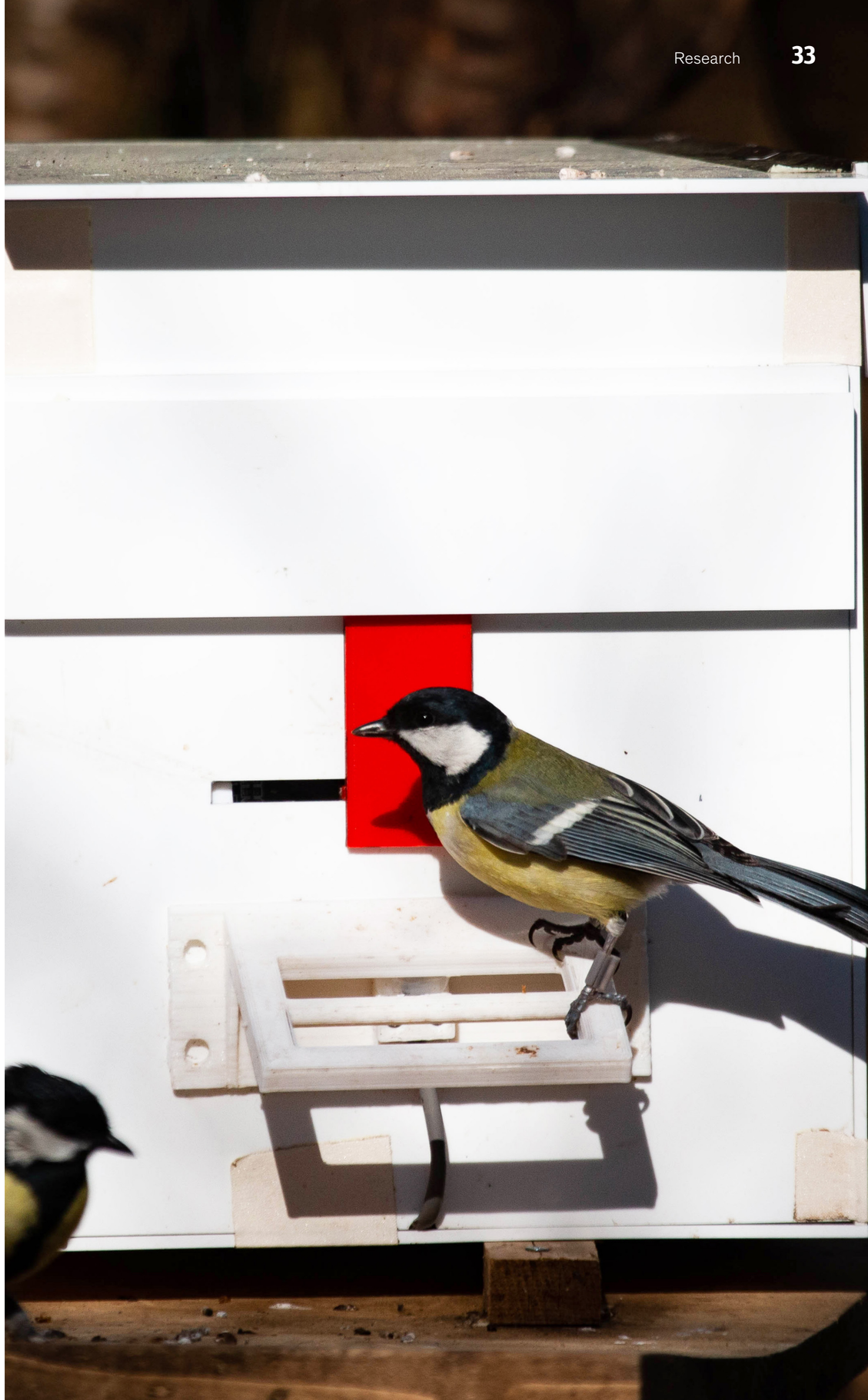
In your opinion, what has been the most relevant progress within the last 12 months?

Sonja Wild We have optimized the design of our selective puzzle box and successfully collected data on the ontogeny of social learning strategies in young birds after fledging. Our preliminary analyses show that although young birds' behaviour appears to be initially influenced by their parents, behavioural choices seem to be updated soon after to match the behaviour performed by the local social environment consisting of peers and other, non-parental adults. We have furthermore successfully tracked associations of young tits over an entire year to analyze how social networks emerge and change across seasons.

Michael Chimento For me, the biggest achievement of the year was the publication of my first PhD chapter on turnover and cultural efficiency.

Can you already tell us if there are any new questions or important aspects that have evolved over the course of the project?

Chimento One new and interesting question is whether and how sensitivity to social information changes over time and what might trigger heightened sensitivity.



How could you benefit from cluster collaborations or beyond?

Aplin After becoming aware of the presence of the internal parasite lungworm in our local populations of great tits last year, Michael and Sonja have continued to work with Salamatu Abdu from the Farine lab (Department of Collective Behaviour) on parasite load, with a paper in preparation related to methods for estimating parasite loads from wild birds. Michael is working with Brendan Barrett (Department for the Ecology of Animal Societies) and Anne Kandler (MPI for Evolutionary Anthropology) on the generative model paper.

Finally, Michael and Lucy have started a new collaboration with Fumihiro Kano, experimentally testing the role of synchrony and joint attention for cultural evolution in humans. This was inspired by many of the approaches we used in birds.

Publication: *Chimento M, Alarcón-Nieto G, Aplin LM (2021) Population turnover facilitates cultural selection for efficiency in birds. Current Biology. DOI: 10.1016/j.cub.2021.03.057*

→ BIRDS CHANGE THEIR TRADITIONS FOR THE BETTER. IMMIGRATION HELPS POPULATIONS SHIFT TO MORE EFFICIENT BEHAVIOURS.

CASCB members Michael Chimento and Lucy Aplin have found that birds are able to change their culture to become more efficient. Populations of great tits were able to switch from one behaviour to a better alternative when their group members were slowly replaced with new birds. Published in the open access journal Current Biology, this research reveals immigration as a powerful driver of cultural change in animal groups that could help them to adapt to rapidly changing environments.

In animals, “culture” is considered to be any behaviour that is learned from others, shared by members of the group and persistent over generations. Cultural traditions are known to exist in many animal groups, including primates, dolphins and whales, rodents and birds. Great tits provide a classic example of animal culture. In the 1920s, birds in a town in Great Britain were observed to open the foil tops of milk bottles to steal cream. This behaviour spread over 20 years until birds throughout the entire country were doing the same. In 2015, scientists experimentally confirmed that great tits were able to maintain cultural traditions. A new way of feeding – what scientists refer

Top: Sonja Wild removing a blue tit from a mist net. Bottom: A great tit using a puzzle box during a captive experiment. Barcode tracking and radio-frequency identification (RFID) technologies allow for automated recording of individuals' behaviour both in the wild, as well as in captivity, as they interact with experimental devices.

to as an innovation – could be taught to a single bird and that solution would be learned by other birds and gradually spread throughout populations.

But for great tits and other animals with cultural traditions, it was still not known if groups can change. Once a tradition has taken root, are animals condemned to repeating the same behaviours or can they pivot to more efficient ones? The new study has demonstrated that more efficient behaviours can outcompete an established inefficient behaviour. It pinpoints a fundamental process – population turnover – as crucial for the ability of animals to change their traditions. The study, which involved teaching wild-caught birds to solve puzzles and fine-scale tracking of their behaviour, provides quantitative support for the evolution of culture.

"Experimental evidence of cultural change in animals is pretty rare, so we were surprised and excited by the outcome," says first author Michael Chimento, doctoral student in the "Cognitive and Cultural Ecology" research group at the Max Planck Institute of Animal Behavior. The research team led by senior author Lucy Aplin, who is a Max Planck Research Group Leader as well as a principal investigator at the Cluster of Excellence CASCB at the University of Konstanz, studied populations of great tits caught from forests around Konstanz. Because wild great tits form changeable social groups during winter, when conditions are harshest, the scientists thought that immigration could play a part in cultural evolution. "These fluid groups could influence how their culture changes as new group members might see solutions to problems with clearer eyes because of their lack of experience," says Chimento.

The researchers used captive populations of wild-caught great tits to ask how fluid social groups might change a socially learned feeding tradition. They formed 18 groups of birds, each with an automated puzzle box that gave a reward. When a bird solved the puzzle, the type of solution, time of solution and identity were recorded using RFID, infrared and computer vision technology. Each group had a tutor that was trained on a relatively inefficient puzzle solution, which then spread through the group. Then, half the groups were kept static and in the other half group members were gradually replaced with new birds from the wild over the course of four weeks.

Despite both types of groups innovating a more efficient solution, fluid groups were much more likely to adopt it as their preferred behaviour. The original residents, who were experienced with the puzzle, were generally the ones who innovated the efficient solution, but did not adopt it as their preferred behaviour. The inexperienced immigrants, on the other hand, picked up on this innovation and did adopt it, amplifying the available social information. Birds in fluid groups were able to solve the puzzle box faster than those in static groups, despite having less overall experience.

"Great tits seem to do well in and among human-made habitats, compared to other species," says Chimento. "Our study shows how their fluid social dynamics might be part of their secret to success and contribute to their flexibility."

Stress transmission in groups

When was the last time you felt stressed? Although stress is an everyday and omnipresent phenomenon, there are still many unanswered research questions. One poorly investigated, but very important field is the transmission of stress within the collective. An interdisciplinary research team led by Hanja Brandl, Marcus Groettrup, Jens Pruessner and Petra Wirtz is investigating psychological stress transmission across birds, mice and humans.

Within their project *Short and long-term spread and modulation of individual psychological stress states in collectives*, the biologists and psychologists observe individuals in groups and try to uncover to what extent our social environment affects our own emotional and psychological condition. They are eager to find out the following: In which physiological systems is stress transmission observable? What are the influencing factors? And what is the role of hormones in transmission across different species?

One very important aspect for the researchers is to set up their experiments in as natural a way as possible. In humans, they observe stress transmission in orchestras as well as psychological synchronization during speed-dating and chess tournaments.

To study mice, the researchers have compiled and validated a Live Mouse Tracker system in their laboratory, which they set up with the help of colleagues from France. The method combines computer vision through a depth-sensing infrared camera that can record the posture of mice, machine learning for animal and posture identification, and radio frequency identification (RFID) of mice implanted with an RFID tag.

So far, the main experiments with mice and birds have been successful. “We were the first to establish a standardized paradigm for social stress transmission in mice, allowing us to conduct pioneering research on the effects of stress in different fields, such as physiology, behaviour and immunology,” says Marcus Groettrup. Due to the COVID-19 restrictions, experiments with humans have been difficult. However, the research team is optimistic about completing the data collection soon. It is certain that we will have a better understanding of why we are stressed when part of a group shortly.

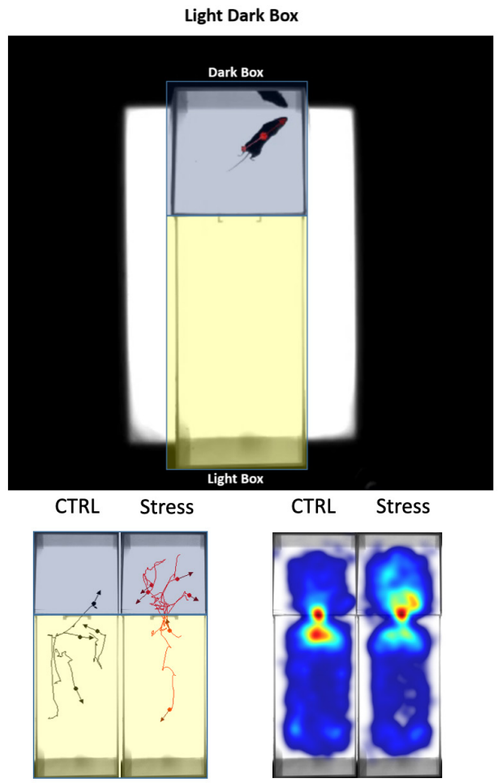
Publication: *Cantor M, Maldonado-Chaparro AA, Beck KB, Brandl HB, Carter GG, He P, Hillemann F, Klarevas-Irby JA, Ogino M, Papageorgiou D, Prox L, Farine DR (2019) The importance of individual-to-society feedbacks in animal ecology and evolution. Journal of Animal Ecology. DOI: 10.1111/1365-2656.13336.*

Denk B, Dimitroff SJ, Meier M, Benz ABE, Bentele UU, Unternaehrer E, Popovic NF, Gaissmaier W, Pruessner JC (2021) Influence of stress on physiological synchrony in a stressful versus non-stressful group setting. Journal of Neural Transmission. PMID 34342736. DOI: 10.1007/s00702-021-02384-2.

Gideon A, Sauter C, Fieres J, Berger T, Renner B, Wirtz PH (2020) Kinetics and interrelations of the renin aldosterone response to acute psychosocial stress: a neglected stress system. The Journal of Clinical Endocrinology & Metabolism. DOI: 10.1210/clinem/dgz190.

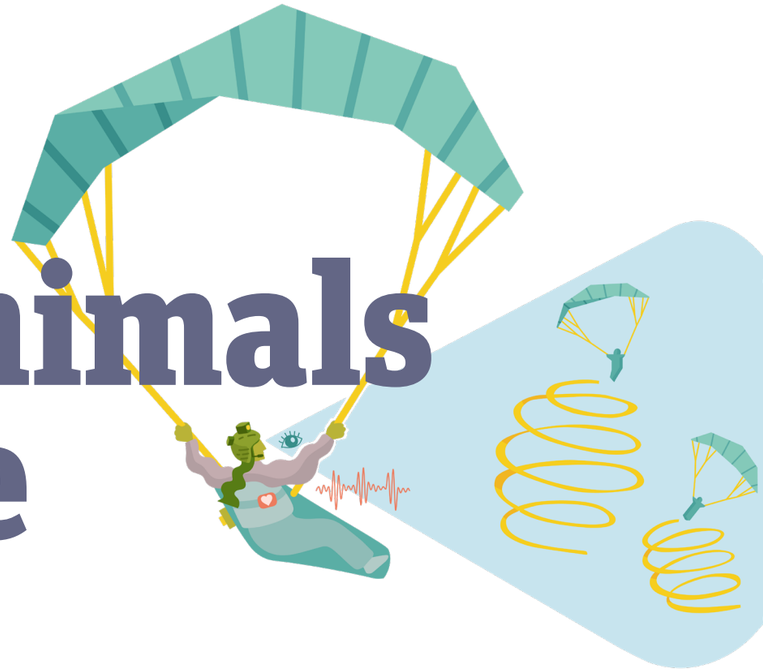
Koerner J, Horvath D, Herrmann VL, MacKerracher A, Gander B, Yagita H, Rohayem J, Groettrup M (2021) PLGA-particle vaccine carrying TLR3/RIG-I ligand Riboxxim synergizes with immune checkpoint blockade for effective anti-cancer immunotherapy. Nature Communications, 12(1), 1-16. DOI: 10.1038/s41467-021-23244-3.

→ **Recordings and sample data from a light dark box behaviour test using Noldus instruments and software.**



Top: *Mouse in a light dark box arena exploring the dark area.* *Bottom:* *Comparison of control and stress groups with visualized tracks (left) and pooled heat maps (right)*

How animals operate



→ HOW FREE-FLYING PARAGLIDERS CAN REVEAL INFORMATION ABOUT THE ANIMAL WORLD

COVID-19 has greatly influenced researchers and many exciting topics arrose not only in direct conjunction with the virus and its impacts but also due to the absence of fieldwork or certain study settings. Researchers needed to think outside the box, which is how the idea to paragliding study by movement ecologist Hannah Williams was born.

Williams wanted to study collective soaring in the vulture and condor species, which required international travel. She is therefore now exploring the mechanisms by which moving beings can gain information on energy from their landscape by observing the energetic investment of locomotion and movements of others.

To do this, Williams and her colleagues attach sensors to a group of free-flying paragliders, including head-mounted units and eye trackers, to identify which social cues they observe during flight in order to obtain up-to-date information on airflows – the energetics of the system. Firstly, they calibrate the accuracy of this technology using the motion capture system of the Imaging Barn in Möggingen. Secondly, they investigate the consequences for human and animal collective movement strategies.

"The project *Social sampling of the energy landscape: observing airflows for cost-efficient collective movements* focuses on an individual using information provided by the collective, but with the data collected we can also approach the question from the larger group level over the spatial scale of a mountain valley," says Williams. She hopes that she can marry these two scales to explore the use of social information in movement energetics throughout the span the next year.

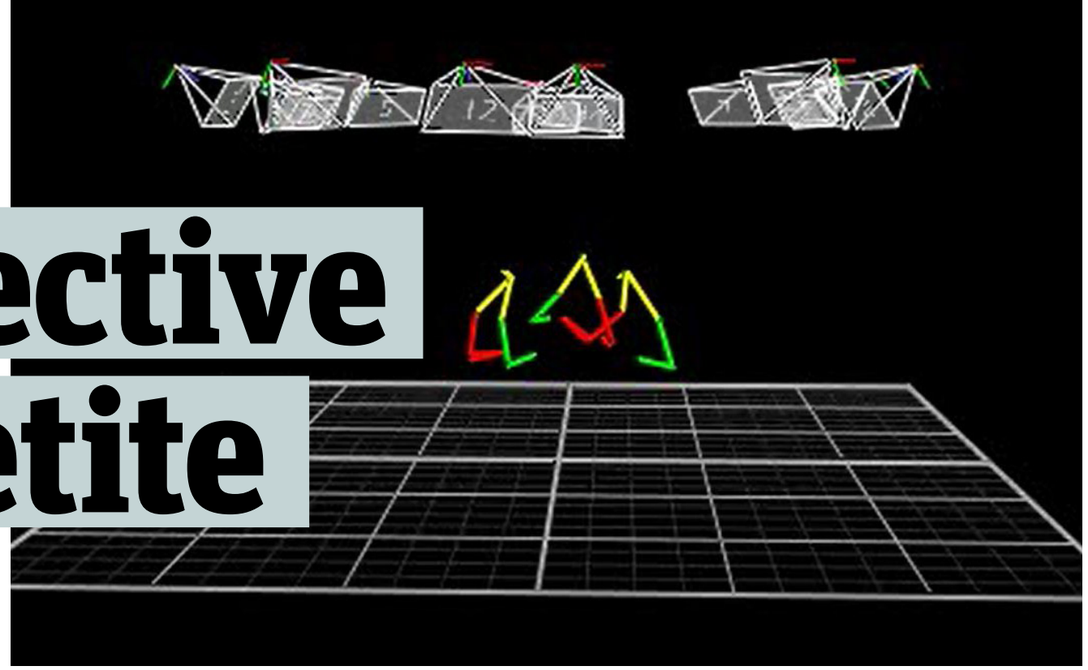
It is a highly interdisciplinary proposal that studies ecology to analyze animal movement, human psychology in terms of individual and collective decision-making to evaluate the risks involved, computer science to visualize gaze in flight (i.e. to see what paragliders see) and mathematics to determine head orientation and eye focus.

→ IMAGING BARN FACILITATES STUDY

Allthough the project only started in May 2021, Williams is sure that her research team will acquire some very important insights: "We are using technology and sports to gain a completely new insight into how animals operate – using the tangible human system and unique technology to look at the world through the eyes of birds." They have also recorded human heart rate during flight. "It is amazing how every decision involves some level of stress," says Williams, following a first look at the data: "Thinking about stress in movement decisions is something that has not been possible to consider in my previous work with soaring birds."

Williams is "very happy", as she says, to have had the luxury of blue-sky thinking and a creative approach to this research. "This has only been possible with the cluster's support and expertise. Without the facilities, we could not attempt to comprehensively investigate the use of social information in free flight and in a natural environment where conditions are highly variable." The researchers are quite sure that there will be more unexpected results and insights from this unanticipated work over the next few years.

Publication: Williams, H.J. & Safi, K. (2021) Certainty and Integration of Options in Animal Movement. Trends in Ecology and Evolution. https://doi.org/10.1016/j.tree.2021.06.013



Collective appetite

How the social environment influences group eating?

Have you ever wondered why the last piece of cake is left untouched when we eat in a group in Germany? Because no one dares to touch it. Maybe you have heard: “It is a matter of good manners” – or in German: “Das ist für den Anstand.” Beyond that, there is a myriad of other eating behaviours. Perhaps they will now be decoded by psychologists Britta Renner, Harald Schupp and Jana Straßheim, together with the rest of the team behind the project *Individual and collective appetite – how is eating shaped by social influence?*

The aim of this project is to determine how social context influences the eating behaviour of human collectives. “In our studies, we analyze behaviours, including kinesics, as well as proxemics, to explore whether there are fine-scale processes of behavioural synchronization or anti-synchronization within a group while eating,” says doctoral student Jana Straßheim.

Perceived synchrony is assessed on individual and group level and through external raters. But the researchers want to take it a step further. “In addition, we want to use automated coding to analyze synchronization and perceived synchrony in greater depth,” outlines Britta Renner. To automate this data analysis, the team is collaborating with the project *Human-in-the-loop analysis* by Daniel Keim and Matthias Kraus. “The innovation in our project lies above all in the fact that behavioural observation studies in groups of humans are very rare,” says Renner.

The team developed a new paradigm for the project, where they study groups of three participants while experimentally varying food presentation and the valence of the group context. Food manipulation involves snacks that are served on a separate plate for each individual (individual task) or on a shared plate from which the participants can snack (joint task). First results suggest that eating from a shared plate increases perceived synchronization as compared to eating from a separate plate.

“Conducting studies with groups has been the greatest challenge due to the changing governmental regulations since the start of the pandemic,” says Straßheim. They also set up a new, mixed-reality commensality design using a videoconferencing system. In this setting, ready meals are delivered to the three participants’ homes and they are asked to eat with their digitally present lunch companions.

The team is working together with three newly funded CASCB projects to add new analysis, such as eye movement. This enables the researchers to look at gaze movement and duration, thus recording attention and eye focus of individuals during a conversation and while eating together. Gaze movement, together with their current measurements of synchronization, helps the researchers to further investigate the underlying processes in collectives.

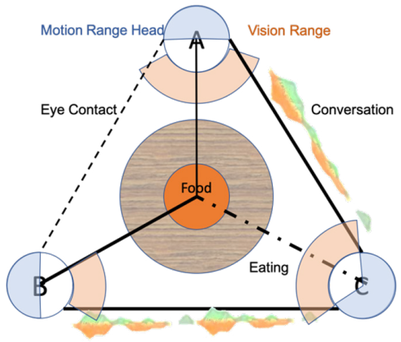


Figure 1: Study setup and conceptualized analysis goals. Three people are sitting around a table and talking to each other while eating. Features such as gaze direction, body posture and conversational context are taken into account for analyzing synchronization patterns between participants.

→ DATA ANALYSIS OF COLLECTIVE EATING BEHAVIOUR

How can data analysis facilitate the extraction of meaningful patterns in collective eating behaviour? Computer scientists Matthias Kraus, Hanna Hauptmann and Daniel Keim are working in the field of human-in-the-loop, which is a branch of artificial intelligence that leverages both human and machine intelligence to create machine learning models. The three researchers are developing a state-of-the-art visual analytics framework for interactive extraction and analysis of behaviour patterns *(see Figure 1)*. The initial prototype focuses on the auditory channel and can be used to analyze and streamline audio data from study trials *(see Figure 2)*. One important step, which is supported by the framework, is speaker diarization, which is the segmentation of a single audio file into individual audio streams per speaker for further analysis. To obtain data on individual and collective human behaviour when eating, the group collaborates with cluster researchers Britta Renner and Jana Straßheim. “Gaining new insights from a study sample in seconds by visualizing an abstraction of its features – without going through the original video recordings – is incredible!” says Keim. They started with a modular base framework that facilitates a complete data analysis pipeline, loading raw study data to the visualization of extracted features. Their next step will be the development of a metric that quantifies sentiment or emotion from sequences of a conversation. “Ultimately, we aim for a deployment of our framework in the evaluation process of future user studies in the domain of psychology,” adds Kraus.

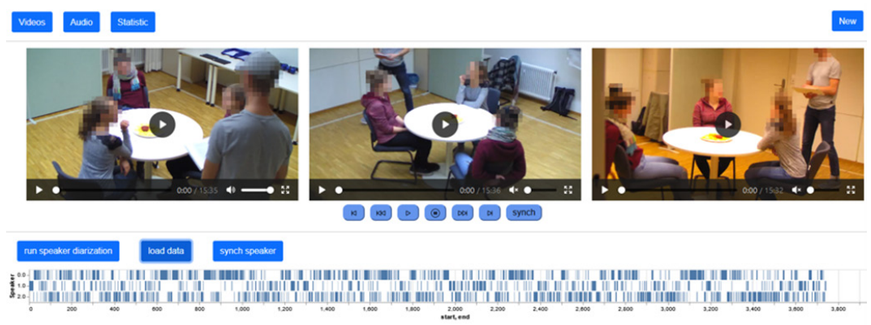
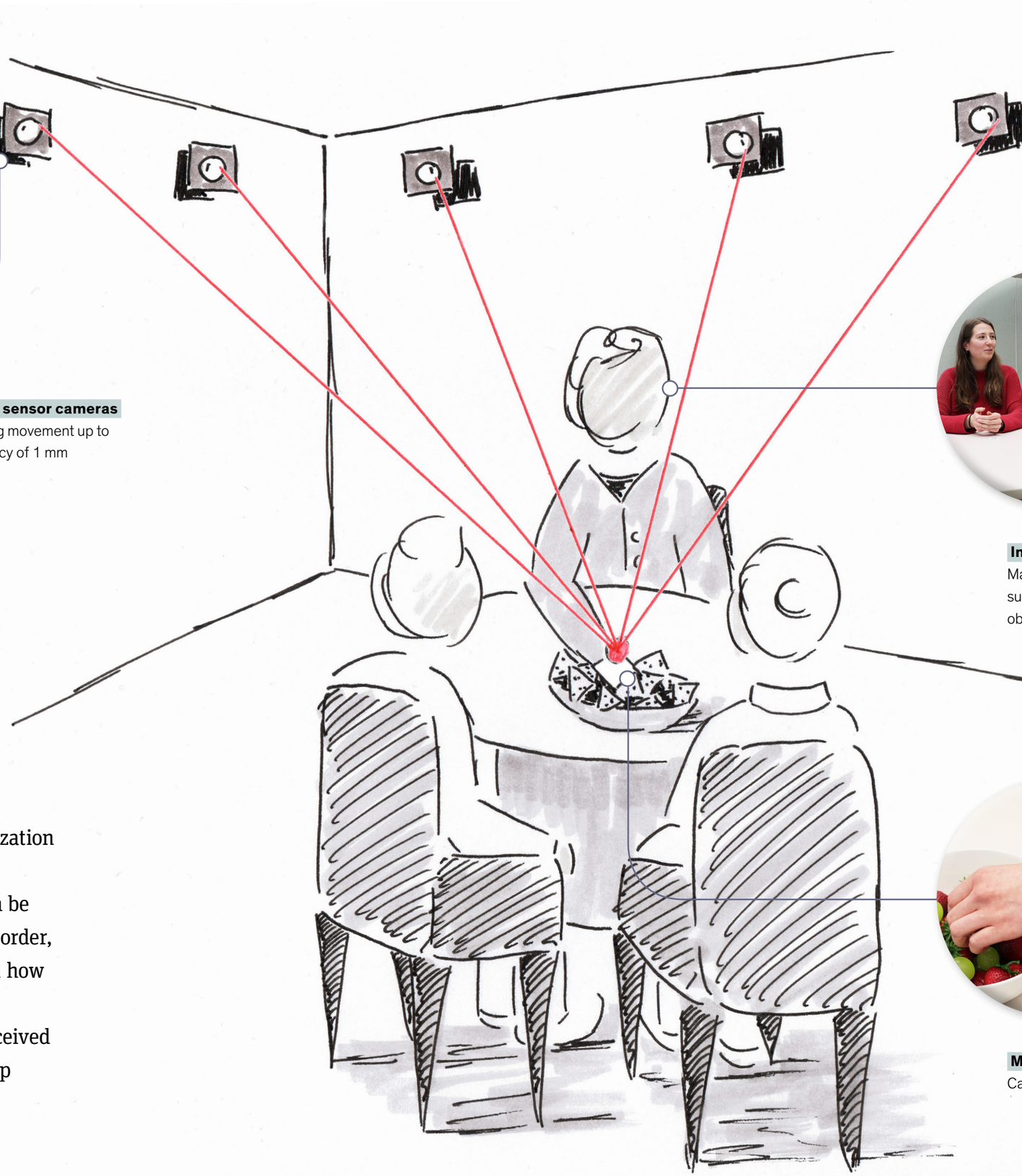


Figure 2: Initial web prototype for the interactive analysis of speaker diarization results, i.e. the results of a semi-automatic segmentation pipeline that splits one input audio stream by speaker.

Laboratory setup

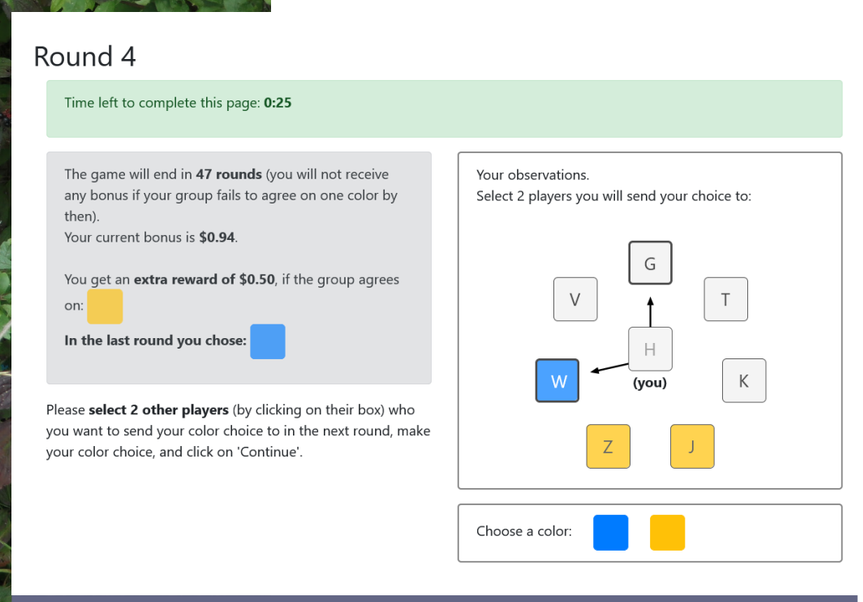
- The setup allows fine-scale measurement of behavioural synchronization and desynchronization
- Thus, when three people sit down to eat, it can be determined who followed whom and in which order, while also having access to who said what and how
- Additional assessment of how individuals perceived their interaction partners as well as their group while eating together

Infrared sensor cameras
Measuring movement up to an accuracy of 1 mm



Interaction
Making aspects of communication, such as kinesics or proxemics, objectivly measurable

Marker
Capturing behavioural processes



How to reach a consensus?

CASCB biologists and psychologists are researching the role of communication structures in consensus decision-making

Imagine a group of several individuals with strong opinions that is required to collaborate. To this end, the group should find a consensus. Not an easy task, is it? How dynamic networked groups achieve a consensus is the research question explored by CASCB researchers Nico Gradwohl, Ariana Strandburg-Peshkin and Helge Giese within their project *The role of communication structure in consensus decision-making in human and animal groups.* "Firstly, we ask how network structure and individual preferences interact, also with regard to outnumbering a global majority based on local interactions. Secondly, which role plays individual control over the interaction partners in the network. And thirdly, how other factors, such as cost of communication or individual differences, affect the strategies that individuals rely on."

To find answers to these questions, biologist Ariana Strandburg-Peshkin and psychologists Nico Gradwohl and Helge Giese are using a combination of online experiments and agent-based models, thereby comparing competing hypotheses and exploring processes. In their online group experiments, participants are incentivized to arrive at a consensus on two alternative options, while each individual can earn additional personal benefits for one of the consensus outcomes. As a further complication, they can only selectively communicate and coordinate with single group members to find a group-wide solution. So who will give up their stance? And why? "Content-wise, the most exciting aspect of this project is learning more about basic forms of communication and low-level interaction processes in consensus formation, which is inarguably a challenge for groups and societies alike," say the researchers.

→ COMMUNICATION STRUCTURE HAS MAJOR RELEVANCE

Already after the test phase, which was recently completed, they are surprised by the results, as Gradwohl says: "Originally, we were mainly interested in situations in which individuals determine to whom they send information about their preferred course of action. However, we quickly realized that the decision about from whom one receives information can also be extremely important and has significant implications for the strategies that individuals should rely on when they select interaction partners."

Eventually, they also hope to gain new insights into the topic of echo chambers. Echo chambers represent an environment where a person only encounters information or opinions that reflect and reinforce their own. This was recently raised as an important issue in the formation of political opinion, adds Giese. "More generally, network structure can affect who is locally, but eventually also globally perceived as a majority, even if that is not necessarily the case," the researchers explain.

After the successful completion of the test phase, they are now running the first empirical projects with humans. But Strandburg-Peshkin reveals: "Connecting and comparing human and animal behaviour on a theoretical level is already being discussed within the group, which will spark further empirical investigations in humans and animals alike."

"The most exciting aspect of this project is learning more about basic forms of communication and low-level interaction processes in consensus formation."

The role of chemical communication in fish collectives

Can information about stress states be transmitted among individuals in a fish collective via chemical communication based on excreted hormones? CASCB member Aneesh P. H. Bose aims to develop and validate a methodology to quantify waterborne hormones from water baths that contain fish in different physiological states. This work will then allow experiments to test whether excreted hormones can act as important informational cues in fish collectives. Five endocrinologists and evolutionary biologists are working together on this project entitled *Collective transmission of psychological states and behaviour in fish*, which takes a novel perspective on information spread in animal collectives. Bose and his team want to lay the groundwork for future experiments on a multitude of topics, including stress transmission, social buffering and social evolution.

Publication: Bose AP, Windorfer J, Böhm A, Ronco F, Indermaur A, Salzburger W, Jordan A (2020) Structural manipulations of a shelter resource reveal underlying preference functions in a shell-dwelling cichlid fish. Proceedings of the Royal Society B, 287(1927), 20200127. DOI: 10.1098/rspb.2020.0127.

Developing universal tools to measure neural activity across species

How can research characterize neural activity in isolated and group-raised fish? To find out, neurobiologist Armin Bahl and bachelor student Maite Börsig have developed an immunohistochemistry-based staining method. Moreover, they are in the process of building a two-photon microscope, which will allow them to depict whole brain volume in deeper layers and even characterize neural activity over time. “The great advantage of the method is that you can even look at a snapshot of brain activity in freely moving animals,” explains Bahl, and it is universally usable across ages and species. Bahl says: “This makes the characterization of neural activity based on immunohistochemical labelling an exciting alternative to functional brain imaging studies.” Bahl is pleased that the results from the project *Brain-wide neural activity representation of larval zebrafish social behaviour* have stimulated new work in his own group, where they seek to test similar questions in older zebrafish, and in the CASCB locust project. In addition, it has led to an increase in collaborative work with the Couzin and Jordan groups.

Determining the different perceptions of inequality and uncovering the consequences of inequality misconceptions

Inequalities in health, wealth and income exist in all societies. However, individuals and societies may perceive different levels and trends in inequality as more or less justifiable. More importantly, concerns about inequality may differ significantly depending on the type of resource that is distributed unequally. The goal of the cluster project *Probing collective misperceptions: Health and economic inequality in comparativeperspective* is to examine and compare the underlying mechanisms of perceptions of inequalities in health, wealth and income. This is important for a better understanding of why individuals over- or underestimate actual levels of inequality. The project started in October 2021. The research team led by health scientist Britta Renner aims to build an interdisciplinary bridge project supported by both Konstanz clusters of excellence, “The Politics of Inequality” and the “Centre for the Advanced Study of Collective Behaviour”.

Publication: Debbeler LJ, Schupp HT, Renner B (2021) Pessimistic health and optimistic wealth distributions perceptions in Germany and the UK: evidence from an online-survey. BMC Public Health, 21(1), 1-10. DOI: 10.1186/s12889-021-11355-x.

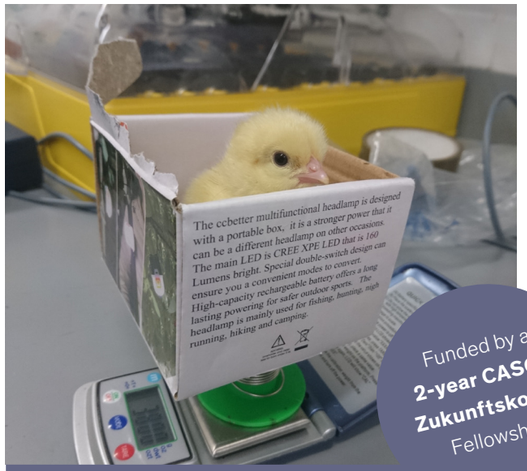
Mechanisms underlying innovation in social animals such as humans

In human societies, innovation is often a collective phenomenon which is closely related to social influence. While innovative ideas require out-of-the-box thinking by some individuals, the dissemination of innovation requires social learning. But what are the motivational and institutional prerequisites of innovation? This major question is addressed by economists Fabian Dvorak, Urs Fischbacher and Susanne Goldlücke in the project *Preferences and incentives for innovation*.

They study the prerequisites of innovation theoretically, but more importantly they conduct laboratory and online experiments to test their theoretic predictions. Early career researcher Dvorak says: “I personally find it fascinating to explore how many our daily decisions are influenced by the behaviour of others. I also want to understand whether there are certain types of individuals who are more or less immune to social influence or like to deviate from the mainstream. I would like to know who these people are, where you can find them and what motivates their behaviour.” The researchers have developed a discrete choice model that combines intrinsic preferences and frequency-dependent social influence, which was “one of the major goals of the project,” as Dvorak says.

Influence of physiological factors on moving social groups

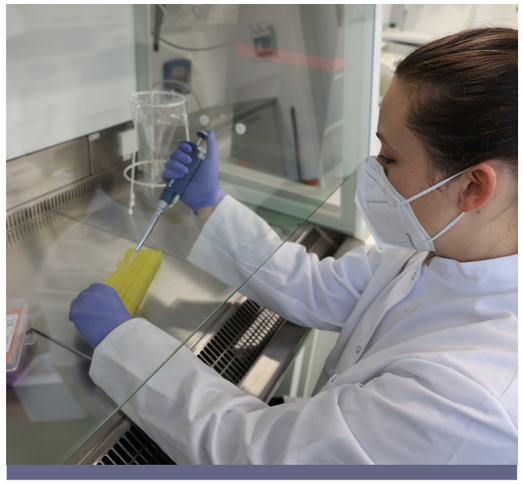
As our social contacts slowly increase again it is nice to see people in the streets, but we are also reminded of old annoyances. Can you remember the last time you had to walk along a crowded pavement? The frustration of not being able to walk at your own pace, or perhaps the feeling of being swept along in a direction you do not really want to go? Have you ever wondered how much these little costs add up to, or if life in the city is really worth the hassle? The overall aim of the project *Energetics of movement and social behaviour*, a collaboration between cluster researchers James A. Klarevas-Irby and Damien Farine, is to quantify the physiological costs that come with life as part of the collective. Biologist Klarevas-Irby is excited: "Using simultaneous GPS (locational), IMU (activity) and ECG (heart rate/physiology) data, and by ground truthing these data with video recordings of specific target behaviours, we will generate the first direct measurements from wild animals of the metabolic costs of living and moving as a group." Understanding the physiological impacts of collective living of individuals within groups will represent a new frontier in the study of collective behaviour. The biggest step towards reaching this goal has been the successful implanting of ECG loggers into 21 vulturine guineafowl in March 2021. Klarevas-Irby says: "Since then, we've been steadily collecting a really interesting dataset, which has only been made more interesting by unpredictable drought conditions driving the implanted birds to make some rather extreme movements, which we're eager to look into."



Funded by a **2-year CASCB Zukunftskolleg** Fellowship

The effect of early life experience on group coordination and communication behaviour of individuals

Early life experiences can affect how individuals signal to each other and therefore affect group coordination and individual survival. Zukunftskolleg fellow and CASCB member Gabriella Gall will investigate the use of vocal signals to coordinate group activities in the common pheasant. "This study with the title *The effect of early experience on individual vocal flexibility and group functioning* will be the first to investigate the interplay between individual social signalling and coordinated group behaviour from embryo to death," says Gall. The ability to manipulate the early social environment of each pheasant together with the application of novel methods for data collection and analysis, i.e. high-resolution movement and acoustic data on all birds within multiple groups, provides an unprecedented opportunity to study how individuals navigate their social and physical environment and will help to understand the fundamental trade-offs faced by animals living in groups. A limitation of many study systems is that group compositions are often fixed, offering little opportunity to measure the same individual in different social settings. The researcher avoids this: "By studying pheasants, a species that exhibits fission-fusion behaviour, I will overcome this limitation and be able to directly compare how individuals behave in different social contexts, providing stronger evidence for social effects while reducing potential confounds of long-established group structure."



Constructing genetic networks through faecal samples

Many hypotheses in behavioural ecology are based on inclusive fitness theory. An understanding of relatedness among individuals is therefore crucial for investigating many questions in this field. It is, however, quite an endeavour in natural populations of difficult-to-sample taxa. A team led by behavioural ecologist Gisela Kopp is therefore assessing the broad-scale feasibility of the novel faecalFACS methodology in the project *Establishing faecalFACS as a method to investigate the genomic relatedness networks that underlie social interaction networks in natural animal populations.* The aim is to derive genetic relatedness networks based on faecal samples from non-model organisms. Kopp is certain: "This will open up completely new horizons for studying the genetic factors underlying (social) interactions in natural animal populations." So far, sample collection has started well. The aim is to establish this methodology for wide application by the CASCB community and beyond.

Bumblebees, ants and honeybees – the relation of their physiological state to their neurochemical state

How is the physiological state of social insects such as bumblebees, ants or honeybees related to their neurochemical state? Neurobiologists Divya Ramesh and Christoph Kleinadam are sure there is a connection, since the behaviour an animal displays is the outcome of both its internal physiological state as well as the sensory environment and its context. The project *'Frame of mind' – How neurochemical modulation mediates context-dependent decision-making in social insects?* brings together classical animal behaviour approaches with chemical analytics. So far, most studies of neuromodulation address the effect of individual chemicals, or only a small handful of them. "In our novel approach, we quantify 13 different neurochemicals and their synthesis precursors, thus providing a holistic view of the neurochemical state of the individuals," says Ramesh. Kleinadam adds: "To have a unified single method that is transferable to all organisms, to subject them to similar contexts and to be able to compare the changes in neurochemical signatures at the level of individual brain parts is cutting edge."

Area B

Signalling in moving animal groups

How meerkats communicate with each other

The exciting question how does vocal communication mediate individual and collective movement in cohesively moving animal groups is addressed by the project *Signalling in moving animal groups*. The research team led by Ariana Strandburg-Peshkin focuses on meerkats, a social mongoose species living in stable social groups. While foraging, meerkats move together throughout the day, employing a range of vocalizations to coordinate their behaviours. Using GPS and acoustic loggers (and more recently accelerometer loggers), researchers collected data on the movement and vocalizations of most individuals from a wild group of meerkats at the Kalahari Meerkat Project in South Africa.

But how can you understand the signals? Strandburg-Peshkin says: “We develop machine learning approaches to extract and classify vocalizations from raw audio streams, thus building up a time series of every call given by each individual within the group and its type.” This data was used to infer how individuals make decisions regarding where to move; whether, when and with what vocalizations to signal; and ultimately, how these decisions combine to shape collective decisions regarding the direction and timing of group movement.

Photo location **Kalahari Meerkat Project**

The work combines boots-on-the-ground field biology with modern computational approaches and thus requires expertise in behavioural ecology, bioacoustics and machine learning. “Moreover, the resulting combined datasets of vocalizations and movement require the development of new analytical tools, for instance to infer influence and leadership and how these are affected by vocalizations,” she says.

“The opportunity to record both movement and communication signals emitted by entire animal groups in the wild is incredibly exciting and paves the way for answering many questions about how communication and coordination interact,” says Strandburg-Peshkin. In addition to testing hypotheses about the drivers of individual and collective decision-making regarding signal production and movement, the resulting analyses can also generate new hypotheses, which can then be tested via experimental manipulations (e.g. via playing back calls).

“Perhaps even more than answering our existing questions, these datasets excite me because of their promise to open up new questions that we had not previously considered. These new tools effectively expand our powers of observation, enabling what I see as a new era of natural history where we may discover patterns that become apparent only when viewed through this ‘bird’s-eye-view’ perspective on social groups.” These patterns can then generate new hypotheses about how coordination systems work, which are potentially testable via field experiments.

While the project started with an emphasis on how vocal communication affects collective movement, over time the team became increasingly interested in what a collective behaviour perspective can bring to the study of animal communication. Strandburg-Peshkin expands on this: “In particular, our data also enable us to study vocal interactions in groups, including turn-taking and call-response dynamics. We hope to explore these topics – as well as their links with the spatial configuration and movement of groups – in the future.”

Publication: Strandburg-Peshkin A, Clutton-Brock T, Manser MB (2020) Burrow usage patterns and decision-making in meerkat groups. Behavioral Ecology, 31(2), 292-302. DOI: 10.1093/beheco/arz190.

→ ARIANA STRANDBURG-PESHKIN ABOUT HER STUDY

In your opinion, what has been the most exciting progress within the last 12 months?
Strandburg-Peshkin In the past 12 months, we were finally able to return to the field and have now collected combined movement and vocal data on several more meerkat groups. We have also added accelerometers to our collars, thus opening up the possibility to obtain behavioural states from all tagged individuals as well as to explore new questions about the coordination of vigilance behaviour. We have also made progress on the machine learning pipeline for extracting and classifying calls, though this is still in development. Finally, we are working on several papers using the collar data, including a paper on leadership in meerkat groups and one on vocal interactions.

Which have been the most relevant challenges within the last 12 months?
Strandburg-Peshkin We were unable to conduct fieldwork in 2020, which greatly delayed our data collection. Fortunately, the Kalahari Meerkat Project was able to continue throughout the pandemic, enabling us to resume our collaring data collection in mid-2021. Other challenges have included some unexpected equipment failures and necessary changes due to several of our equipment components being discontinued.

What steps or important milestones are coming up next?
Strandburg-Peshkin We are currently preparing two papers using the tracking data – one on leadership and the other on vocal interactions – and hope to submit these in the near future. We are also working on a perspectives piece about what can be learned from the integration of collective behaviour and animal communication and the new possibilities afforded by our high-resolution tracking methods at this interface. To test hypotheses generated from our preliminary analyses of the existing tracking data, we have also been working with collaborators to carry out audio playback experiments in the field while tracking collars are deployed.

Did you experience any new synergies to other cluster-internal (or -external) projects since the project started? If so, which ones?
Strandburg-Peshkin Due to the overlap in team members as well as the topical overlap, we have been interacting frequently with the new project *The role of communication structure in consensus decision-making in animal and human groups*. This interaction has also helped form stronger connections between the social psychology and biology communities. We have also started discussing with linguists and computer scientists at the University of Konstanz who are interested in connections between human and animal communication systems, which we are interested in developing in the future. Outside the university, this project has connections to a larger collaborative project, *Communication and Coordination Across Scales*, which is investigating communication and group coordination across multiple species that use vocal communication to coordinate within varying spatial scales and behavioural contexts.

Migration of bats

The interaction between social behaviour and resource distribution

When thinking about migration in the animal world, most people probably think at first about the migration of birds. But what about the migration of other animal species? Edward Hurme and his colleagues Martin Wikelski and Dina Dechmann are studying the migration of straw-coloured fruit bats within their project *Automated tracking methods and interactive virtual environments*. They track the green wave across Africa with ICARUS tags.

"This is the first project to conduct long-term GPS tracking of migratory bats," says Edward Hurme. "While migration has been inferred in several species, it is yet to be clearly demonstrated through tracking." The postdoctoral researcher and his colleagues also collect samples to look at age, diet and viral load in order to understand how these factors influence migration. The aim of the study is not only to explore the migration route but also how individuals and groups respond to natural changes in the environment on a large scale. "We already discovered that bat migration is correlated with the green wave, i.e. increase in greening typically seen during spring or the beginning of the wet season," says Hurme. "Additionally, this pattern was stronger in larger colonies, suggesting that collective sensing may improve migration timing. We can now develop new hypotheses from these results that we can test on data from individually tagged bats."

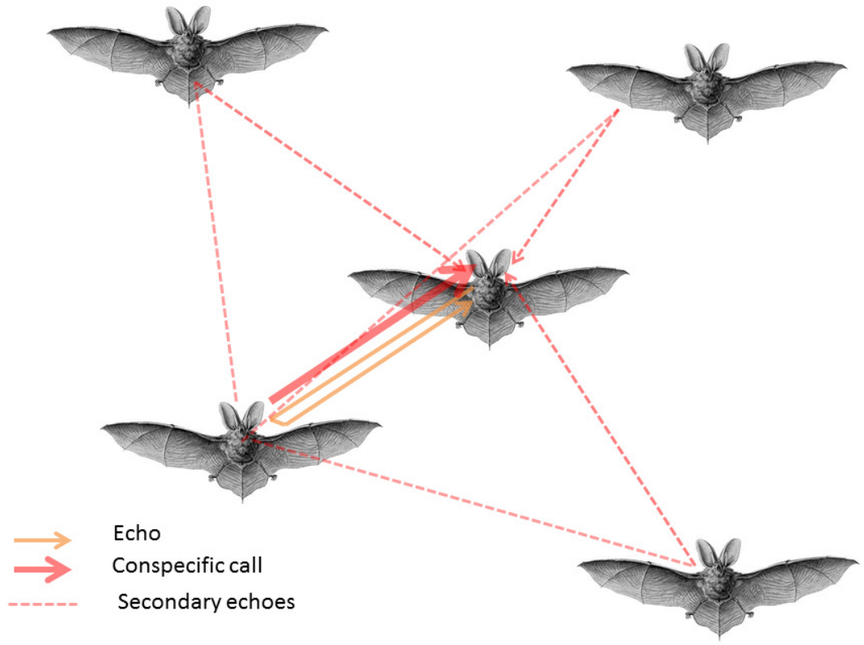
→ FIELD STUDY IN FOUR AFRICAN COUNTRIES

To achieve this, they tag roughly 30 individuals per country. They plan to implement the field study in Rwanda, Zambia, Cameroon and Ghana. "Additionally, we will monitor colonies across Africa through a monitoring network composed of volunteers conducting monthly counts as well as use camera arrays combined with imaging software to provide detailed counts for colonies that are too large to estimate manually," comments Hurme. The CASCB members are therefore working together with local researchers, conservation groups and community leaders to conduct monthly counts of bat colonies. In addition, they have developed a computer vision method to conduct more accurate counts in colonies with over one million individuals.

"We already discovered that bat migration is correlated with the green wave, i.e. increase in greening typically seen during spring or the beginning of the wet season."

Edward Hurme feels certain that they will advance the study of collective behaviour: "Focusing on the migration of a large fruit bat in Africa will add to our understanding of migration because there is little information on migration in bats, frugivores or species that move solely throughout the tropics." What particularly impresses him is that this species forms colonies of thousands to millions, providing opportunities for individuals to benefit from social information. "While we have yet to fully tease apart their collective behaviour, this species seems to be a good candidate for collective migration."

Collective sensing and motion of bats



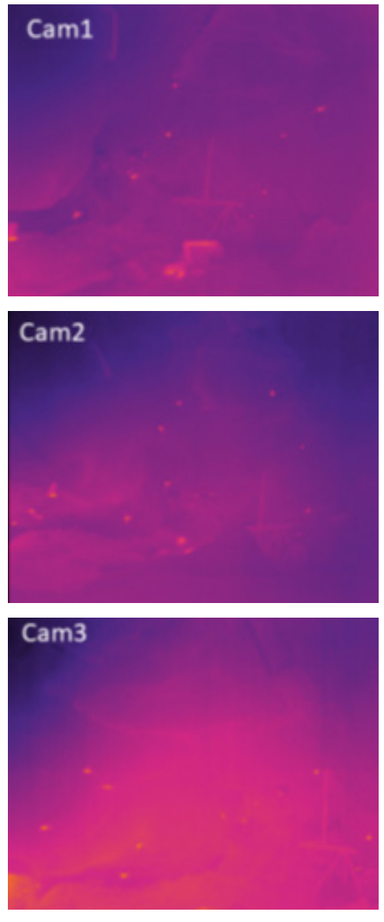
Imagine being inside a cave. There is no light. You are surrounded by absolute darkness. This is Thejasvi Beleyur's research setting: the Orlova Chuka cave in Bulgaria. Beleyur is interested in how animals move and sense each other when they are in groups and have limited information about their surroundings. He studies groups of echolocating bats that jam each other due to their loud calls, but still manage to listen to faint echoes to detect each other.

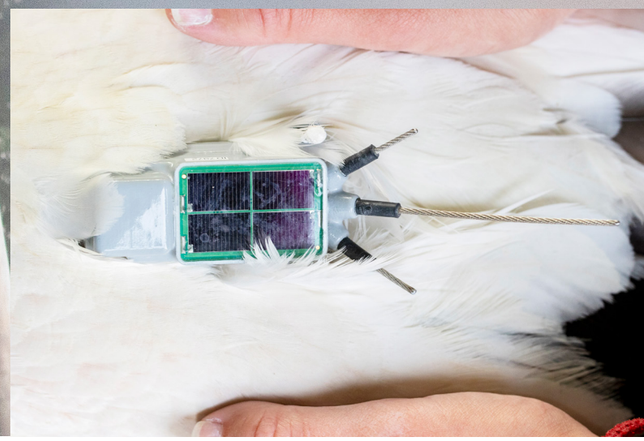
An important aspect of Beleyur's research is that he studies bats in their natural environment. He uses acoustic as well as video-tracking systems and matches the bats' behaviour to their position in space by aligning the tracks with LiDAR scans of the cave. LIDAR thermal aligning has already been done in 'domestic' settings, such as offices, buildings and cityscapes. But alignment in the wild, such as in caves, has not been attempted. "The complex shapes and thermal gradients in natural scenes required some extra processing, and computer scientist Bastian Goldlücke and I learned a lot about how well the existing algorithms work," says Beleyur.

Did the effort pay off? Beleyur confirms that it did: "Many species will not show the same collective behaviours under lab conditions. The so-called Ushichka dataset – an ode to the place where the data were collected – overcomes both these limitations, as it collects multi-sensor data of up to 30 bats flying around happily within natural conditions." He continues: "Echolocating bats form extremely large gatherings and show some of the most impressive examples of collective behaviour. I argue that they have only been studied in one or two modalities at most in terms of the data collected, such as audio or video. Even lab experiments can only go so far regarding the number of bats you can put in a room."

"The so-called 'beamshapes' package could be used to study acoustic communication and model sound radiation in birds, humans, meerkats, etc," says Beleyur. The methods developed in this project can therefore be used for other model systems. It is also published as an open source implementation. In the future, Beleyur plans to perform collective behaviour modelling based on this data.

What are some interesting outcomes of this experiment? "The challenge when groups of bats move together is that they effectively 'blind' each other," says Beleyur. "Each bat emits really loud calls that prevent other bats from hearing echoes. Modelling shows that the bats are probably flying in a 'hyper-stroboscopic' reality, where they detect each other only every now and then because of all the mutual deafening from the loud calls. Not much is known about how bats actually show collective behaviour, despite the fact that each individual experiences this 'hyper-stroboscopy' when in groups."





Collective sensing over multiple scales during migration

Modern tracking technologies and data visualization tools are revolutionizing the ability to study animal movement in the field. With the goal of revealing how long-distance soaring migrants, such as white storks, integrate environmental and social information when making migratory decisions, Andrea Flack, Ellen Aikens and Martin Wikelski are monitoring the white stork population in Southwest Germany with high-resolution GPS devices.

This lifetime tracking approach monitors the movement of individuals from hatching until death, including the early developmental stage when learning is most likely to occur. "Using this method over a long timescale, we reveal how migration routes develop and how individuals respond to environmental changes," explains Andrea Flack. "In addition, by monitoring large numbers of individuals, we are able to detect and characterize social interactions, social learning and collective behaviour by characterizing the location and the dynamics at interaction hotspots, such as locations where individuals regularly and repeatedly encounter conspecifics."

The research team has created this unique study that advances the field of movement ecology by tracking a large number of individuals and their social environments throughout their lives, and eventually across multiple generations. "These types of data and analytical tools are unprecedented and enable us to tackle the grand challenge of understanding the role of social influence during migration," says Ellen Aikens.

Current research in their project *Collective sensing over multiple scales during migration* focuses on analyzing the lifetime tracking data to understand how migration routes are developed over the stork's lifetime. They are also characterizing hotspots of social information along the migration route as well as investigating how migration timing influences group composition during migration. As the project continues, they aim to extend the lifetime tracking dataset to record migrations of multiple generations to provide additional insights into the development of migration culture.

"The technological revolutions that allow better data collection on both animal behaviour and the environment that animals are moving through opens up new opportunities to study questions that a decade ago were nearly impossible to address," remarks Andrea Flack. The team is hoping to answer a key question in animal migration research with this project: How do migratory animals integrate social information when making migrating decisions?

Publications: Aikens EO, Bontekoe ID, Blumenstiel L, Schlicksupp A, Flack A (In Prep). Viewing animal migration through a social lens. Aikens EO, Fiedler W, Wikelski M, Flack A (In Prep). Learning shapes migratory behavior: evidence from lifetime tracking of a long-distance migratory bird. Kauffman MJ, EO Aikens, S Esmaeili, P Kaczensky, A Middleton, KL Monteith, T Morrison, T Mueller, H Sawyer, and J Goheen (2021). Causes, consequences and conservation of ungulate migration. Annual Review of Ecology, Evolution and Systematics, 52: 453–78. https://doi.org/10.1146/annurev-ecolsys-012021-011516

Social interactions of female and male Montagu's Harrier in Spain

How ICARUS tags revolutionize research possibilities

The migratory raptor, Montagu's Harrier, lives in colonies while breeding in the north, where individuals usually return to the same site as in previous years. During winter, individuals of the same colony might be separated south of the Sahelian region by thousands of kilometres. The research team led by C. Giovanni Galizia, Brigitte Geiger and Ajayrama Kumaraswamy studied a colony in Extremadura, Spain. "In previous studies, we tagged females and males with GPS-GSM devices to study their movements and social interactions within Spain during pre-breeding, breeding and post-breeding," explains Galizia. Naturally, they first asked themselves: How do individuals interact both within a colony and with other colonies?

Galizia is still overwhelmed by the results: "For the first time, we could show that females, after breeding or after nesting, took off to places occupied by other colonies of Montagu's Harrier 90 – 270 kilometres away to spend up to 80 days there before starting migration. Males remained at the breeding site until migration started." Biological fieldwork was necessary to tag the animals. And finally, state-of-the-art computer science is used to handle the huge amount of data created by the tags.

Several questions remained. Galizia comments: "We did not know – so far – how the breeding area related to the place of birth." Second, they were interested in how females and males disperse in relation to their parental colony. "In the new project, we tagged juvenile birds with ICARUS tags," says Galizia. "These tags are lighter than the previous tags we used, thus allowing us to tag juveniles. In this way, we will be able to investigate our research interest." That was only possible because of new techniques: Special tags were developed that communicate with the ICARUS team via the ISS.

Juveniles could be tagged for the first time

The innovative character of the latest campaign is twofold: The ICARUS tags are still in an experimental phase, and their usage with different species is an important aspect in developing them further. On a biological side, it is probably the first time that researchers could deploy tags that are lightweight enough to allow for juveniles to be tagged.

Even though the results are already fascinating, there is still a lot to explore: "We would like to follow more fledglings in order to find out about dispersal – also to see whether fledglings tagged at the end of the season try to disperse within Spain or start migration from the nesting site." They therefore need to tag more juveniles, in particular juveniles that hatch later in the year, which are reported to have less likelihood of survival.

Publication: Berger-Geiger B, Heine G, Kumaraswamy A, Galizia CG (2021): Changing places: spatial ecology and social interactions of female and male Montagu's Harrier (Circus pygargus) in the Spanish Extremadura. Journal of Ornithology, 2021.

See also the interactive flight traces at: https://neuro.uni-konstanz.de/harrier.htm

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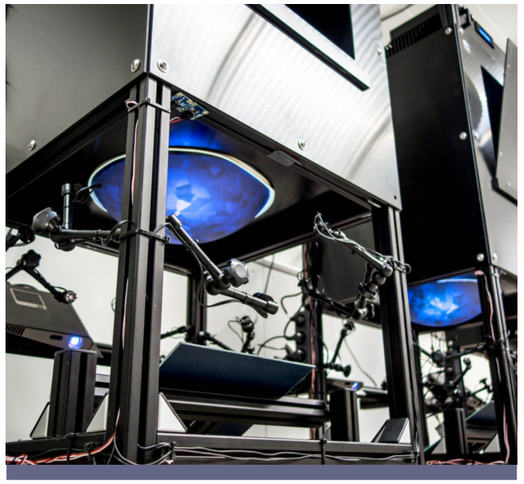


Social interactions during collective decision-making in fish

Fish are known to respond to optomotor stimuli and it has been proposed that the stimuli could be the origin of schooling behaviour. Nevertheless, all optomotor stimuli are always presented as projections on the bottom of the tank, or as stripes moving outside the fish's environment, and never moving with the fish. Daniel Schardosim Calovi and his colleagues built an immersive VR for their project *Using immersive virtual reality to reveal the dynamical structure of social interactions during collective decision-making* which allows them to have a three-dimensional environment and stimuli and compare optomotor stimuli and social ones. It has already shown promising results, where fish interact socially by engaging the stimuli at the same depth, while environmental stimuli cause them to mimic the movement direction, but at the surface of the tank. The team is excited about understanding how fish interact with conspecifics and their environment. Unfortunately, a flood at the lab destroyed their set up, which created a major challenge. On the bright side, they were able to clone one of the flooded FishVR setups and are, therefore, able to reconstruct the damaged machines.

From the coordination of individual brains to effective collective decision-making

How the coordination of individual brains to effective collective decision-making occurs is studied in this two-part project with the title *From the coordination of individual brains to effective collective decision-making*. The first part, supervised by Wolfgang Gaissmaier, focuses on key determinants of collective decision-making, including social learning, characteristics of the individuals, incentive structures and strategic components.

The results feed into the follow-up project *Collective foraging and social search in vast decision-making spaces,* spearheaded by Wataru Toyokowa, which will begin shortly. The aim of the new project is to study collective foraging and social search in vast decision-making spaces.

The second part of the project, led by Harald Schupp, studies neural underpinnings of coordination and collective decision-making. Recent research focused on collaboration using a newly designed experimental game in which dyads had to navigate a Pacman icon through a maze to reach a common goal. The task required participants to exchange information and continuously switch roles. First results indicate that a specific event-related potential component serves as a dynamic marker of stimulus relevance among collaborators.

Interaction among different fish species

Cooperation is found within many animal species, but cooperation between species is rare because it requires mutual benefit and potentiall coordination. "During a field course in Corsica, we found the first potential evidence for cooperation between two different fish species," says PhD candidate Myriam Knöpfle. That was the birth of the new project *Coordination and cooperation across species boundaries* by Knöpfle and Alex Jordan. They observed that a goatfish species (Mullus surmuletus) provides food for other fish as a by-product of its own feeding behaviour by disturbing the sediment and frightening invertebrate prey into the open water. They noticed a novel behaviour during this feeding interaction: tactile stimulation. Their plan was to investigate this specific observation more closely during another field study in Corsica. Due to unexpected complications with using the field station's laboratory and equipment, the researchers have not yet been able to conduct all research. Nonetheless, Knöpfle is fascinated by the observations: "What excites me the most about this project are the fish and their behaviours. After watching them feed for many, many hours, one cannot but love and adore them. They made me aware of how important touch is, also for humans."

Social interaction in bats

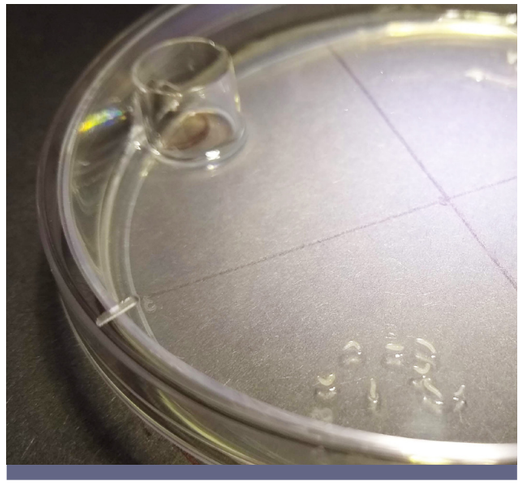
To understand collective behavioural outcomes of animals in the wild, it is essential to consider the ecological and evolutionary forces at play. The project *Testing the ecological and evolutionary drivers of social information use in foraging bats* specialized on ephemeral insect prey by Jenna Kohles and Dina Dechmann combines biologging with camera trapping of the prey landscape and physiological measurements of energetic balance to test the ecological and evolutionary drivers of social information use in foraging bats specialized on ephemeral insect prey. With the biologging technologies available during the last decade, experiments tracking flight and calling behaviour of bats had to be performed separately. That is why the true drivers of these behavioural outcomes are still not disentangled. Using new, cutting-edge technology in the wild, the team can now quantify and integrate dynamic social networks of whole social roosting groups of foraging bats with synchronized networks of the social information available to them from group members. The researchers will complement these two data networks with motion data revealing flight behaviour and trajectories.

Neurobiology of social behaviour in insects

By means of state-of-the-art molecular and analytical techniques, Divya Ramesh, Einat Couzin-Fuchs and Morgane Nouvian want to derive the neural mechanisms of social behaviour in insects. Their research objects are locusts. “The fascinating aspect is that locusts become ‘social’ and highly eusocial insects like honeybees only transiently,” explains Ramesh. The researchers use immediate early genes to look at neuronal activity. This method has been established for a few insects, but not for locusts. “This would be a first step in understanding the regions of the brain involved in the phase transition seen in these insects,” explains the team, which is moving forward with its research work. In 2021, they made excellent progress with mass spectrometry and started to develop in situ hybridization protocols for monitoring the expression of immediate early genes in locusts. Now they are looking forward to working on the behavioural assays for group marching in locusts in the new labs of the VCC.

Patterns of locust collective behaviour

The project *Collective motion while foraging in nutritionally-imbalanced environments* aims to identify patterns of collective behaviour in locusts that emerge in nutritionally-imbalanced environments. Since nutritional deprivation drives collective motion of locusts and since the animals strive to maintain specific ratios of carbohydrates and proteins in their dietary intake, the research team led by Vishwanath Varma predicts that environments with greater variation in nutritional content would facilitate synchronization of movements and feeding patterns of locusts. To this end, they presented two food patches with a balanced or imbalanced composition of proteins and carbohydrates to groups of 30 locusts in 1.2 × 1.2 m arenas and recorded and tracked their feeding behaviour and activity. The most important progress so far has been assembling the experimental setup and the construction of an agent-based model for making predictions. Varma says: “We noted a strong preference for carbohydrate-rich food in locusts and observed intake ratios comparable with known intake patterns.” Trials with alternative food patches are ongoing, and the team hopes to identify one that is sufficiently attractive for conducting further experiments but can also be precisely controlled in terms of nutritional value. Attempts are also underway to improve the accuracy of tracking individual locusts.



Neural circuits underlying state and context-dependent behaviour of Drosophila larvae

“I am always fascinated how flexible we are in our responses to other individuals or towards stimuli,” says neurobiologist Katrin Vogt. Our decision on how to behave depends on the environmental context and also on our internal state and mood. “It is the brain that integrates this information and enables this flexibility, and I am excited every day about solving the puzzle of how it does that.” But there are still many open questions in the area of state- and context-dependent behaviour. Vogt herself is working with Drosophila larvae to gain a better understanding of the neural basis of flexible behaviours. To find answers to these questions, she is recording behaviour experiments with genetically modified fly larvae and analyzing data with the tracking software Trex, published by the Couzin lab. Soon, Vogt hopes to enrich the cluster environment “by adding a deeper understanding of the neural mechanisms underlying decision-making, which is very probably also applicable to other species studied in the cluster.”

Information-sharing and social generalization in collective risky decision-making

The aim of the project *A Computational approach to information-sharing and social generalization in collective risky decision-making* by Wataru Toyokawa was twofold: (1) To develop theoretical models and conduct interactive online behavioural experiments to identify under which conditions social learning and information-sharing strategies yield adaptive and maladaptive group behaviour, and (2) To estimate cognitive processes underlying integrations of socially shared information and individual experiences in search problems using computational modelling. Focusing on computationally tractable gambles, the project’s goal was to establish a research paradigm that will be scaled to more complex questions tackled in larger projects. The project’s results will be published soon. Toyokawa says: “I believe that the reinforcement learning models used and developed here should be general enough to apply to non-human animals too.” This will soon be proofed because Toyokawa will collaborate with animal researchers in the cluster to synthesize understanding of different systems within a unified computational learning model.

Area C

Mapping honeybee nests

How machine learning software can help

The ecological dominance of social insects is partly due to their ability to allocate tasks among nest mates. Task allocation is organized by age, but also spatially within the nest. Young bees perform brood care in the centre of the nest, middle-aged bees process honey at the periphery and old bees exchange information at the entrance. However, these nest areas can change rapidly, for example during a nectar flow. Researchers must therefore regularly "map" the nest contents to determine which areas of the nest are being used for which purposes. To do this, Ben Koger and Michael Smith are designing a deep learning-based software that will automatically label the nest contents from images of honeybee combs. After the model has learned from images of manually labelled comb contents, the software will be able to classify each pixel based on this manual input and label it as part of the comb, pollen, nectar, eggs, larvae, etc. The researchers use methods from the field of biology to answer important questions about bee ecology, management and conservation, as well as computer science techniques for more efficient data collection. This allows them to pursue questions that were previously unsolvable.

→ BEN KOGER EXPLAINS THE GENERAL BENEFITS OF THE STUDY

What new research results have you already been able to generate through your approach?
We are using this to study the weekly comb building and nest use of eighteen honeybee nests at the University of Auburn in the United States. Michael Smith and I are both looking at how natural nests develop over time. We are observing how adaptable bees' nest-building strategies are when they are forced to adapt to new physical conditions.

Have you ever thought about applying your results to other animals? For which other social insects would it also be suitable?
You can think of this as a kind of landscape mapping. This means that, beyond insects in particular, the most relevant other applications would be about quantifying space use in other environmental contexts. In the case of the bee comb we are looking at the scale of comb cells that are less than a centimetre. But if you imagine how agricultural fields look from an airplane or a satellite, like different coloured grids, it is actually not so different. We could therefore actually use a very similar approach to automatically classify which crops are growing in different fields and see how humans allocate their space for different tasks throughout the year, just like we are doing with the bees.

How can beekeepers benefit from your research?
One thing we are quantifying is the natural progression of a healthy hive. Beyond that, when a hive is forced into a configuration that is not ideal, which aspects are the bees able to fix and recover from and which aspects are fixed and potentially going to lead to long-term negative effects. Once we understand this, it will be much easier for beekeepers to judge throughout the summer if their hives are progressing well, or if maybe something is going off track, and which measures they should be taking to correct things before it becomes a real problem. For instance, perhaps by shuffling the order of some of the frames in the nest the beekeeper can shift the direction of development and re-establish healthy growth.

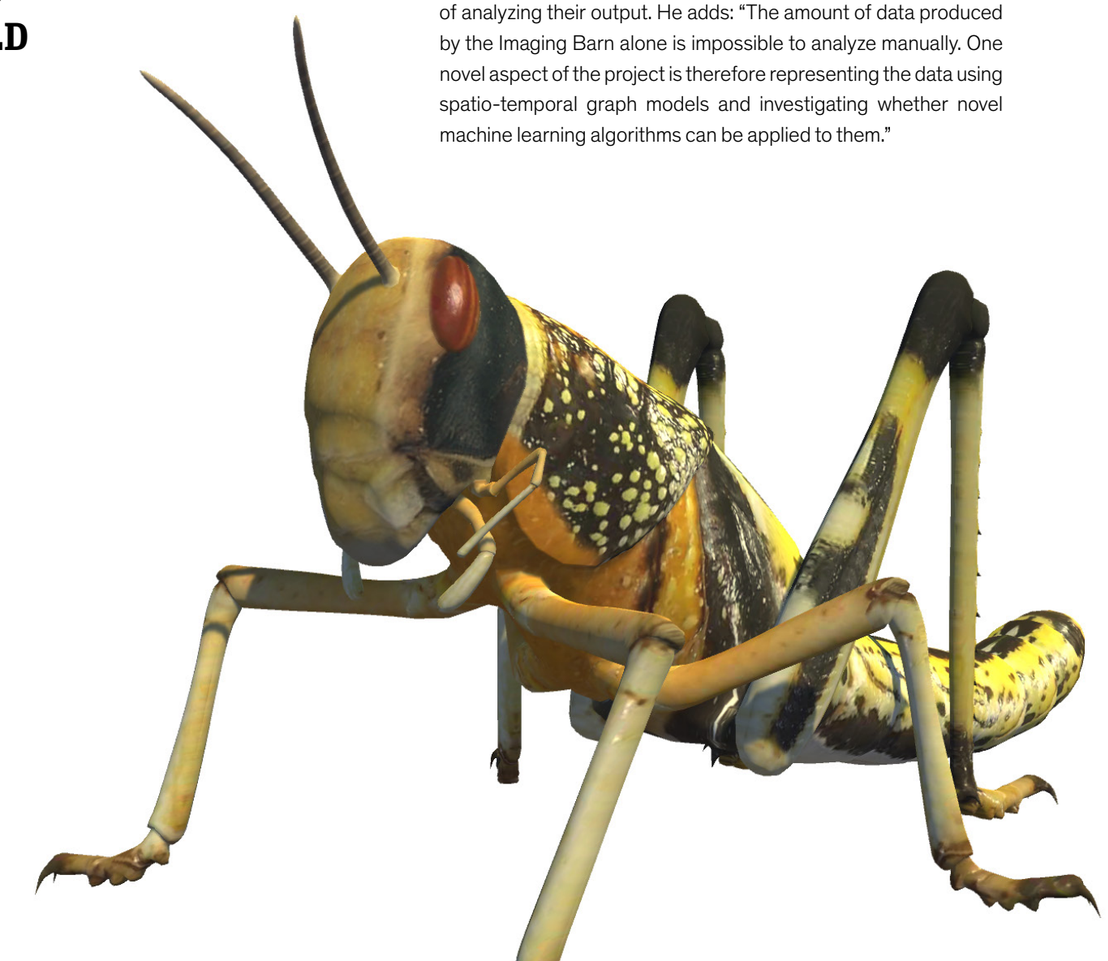
Would developing the software further as an app, e.g. for hobby researchers, be an option?
It would be. All you would need is a cell phone camera to take pictures of the comb and an internet connection to send the images to the cloud for processing. We will have to think about this.

Automated tracking methods and interactive virtual environments

→ HOW COMPUTER SCIENTISTS ARE HELPING TO EXPLORE AND INFLUENCE THE ANIMAL WORLD

Many cluster projects are observing and tracking animals. The development of real-time solutions for interactive virtual environments for animals and improving real-time tracking in the Imaging Barn, and soon also in the new Imaging Hangar at the Centre for Visual Computing of Collectives are, therefore, important steps. Furthermore, the massive volume of data generated by these tracking systems must be processed. These three topics are the overall goal of the project *Automated tracking methods and interactive virtual environments*. The project team supervised by Bastian Goldlücke, Oliver Deussen and Michael Grossniklaus has already supported several other projects successfully, such as the locust study and a fish project.

"In the LocustVR, we used a reduced polygon version of the virtual objects to allow a simulation of an infinite swarm using up to 100 virtual locusts. To achieve this illusion of infinity, we remove objects that are far from the view of the focal locust and respawn them from behind," says doctoral student Mariam Mahmoud.



→ INTERACTIVE VIRTUAL GAME FOR CICHLID FISH

The team created an interactive virtual game where cichlid fish can interact with an animated virtual fish. Paul Nührenberg developed a tracker using the latest version of YOLO, a state-of-the-art object detector, which allows real-time tracking of the fish. Mahmoud, computer scientist, explains her part: "We implemented a low latency network streaming software to transmit the output of the tracker to the VR software in real time, which in turn will trigger a reaction from the virtual fish based on a predefined set of actions. For the interactive virtual environment, we use the Unity platform, which includes built-in, real-time rendering capabilities." Mahmoud is excited to have the opportunity to "investigate novel research from one field and adapt it to new disciplines." She says that last year's most relevant progress was seeing locusts and fish react to their lab-developed visual stimuli.

But what makes this project so unique? Oliver Deussen explains: "The Imaging Barn and the VR setups are one of a kind and therefore require novel methods and solutions." Besides adapting state-of-the-art tracking and rendering methods, there is also the challenge of analyzing their output. He adds: "The amount of data produced by the Imaging Barn alone is impossible to analyze manually. One novel aspect of the project is therefore representing the data using spatio-temporal graph models and investigating whether novel machine learning algorithms can be applied to them."

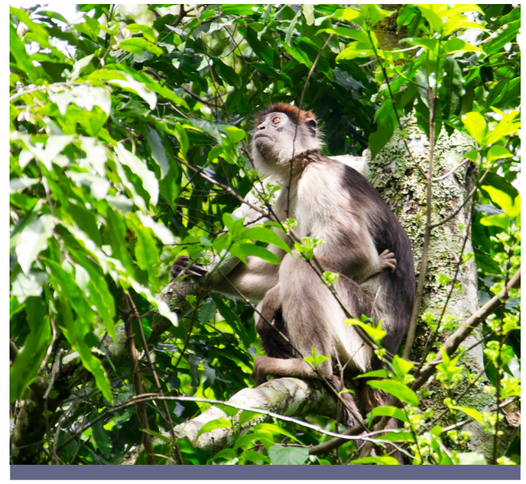
Bird's-eye view on gelada monkeys

Could drones help observe gelada monkeys? Blair Costelloe and her colleagues, Ben Koger and Jeffrey Kerby, see great potential in this. Their goals are to assess the feasibility of using drones to observe gelada monkeys, establish protocols for collecting drone-based data in the context of an ongoing, long-term study of the gelada population, establish the necessary infrastructure at the field site to support drone-based data collection and collect preliminary proof-of-concept data to support external grant applications.

"It's always exciting to get a new perspective on a study species," says wildlife biologist Costelloe. In this case, the new perspective is literal! "A bird's-eye view highlights patterns and phenomena that are simply not observable from the ground. I think once we start getting footage from the field, we will have a long list of exciting questions to tackle."

This project is the start of a broader effort to combine state-of-the-art, drone-based behavioural observations with conventional collection of behavioural data in a long-term study of a wildlife population. "We think this combined approach will allow us to answer questions that would not be possible to address using either approach in isolation," says ecologist and geographer Kerby. For example, drone-based observation allows for precise quantification of spatial relationships and movement trajectories for all filmed individuals, but the distance of the drone does not allow for identification of individuals. This long-term study, the Guassa Gelada Research Project, has already generated 12 years of data on more than 500 known individuals from which ~ 200 are still living. The researchers have habituated the monkeys to allow for behavioural observations from within the herd. COVID-19 and the political unrest in Ethiopia have put their fieldwork plans on hold. However, they hope it will resume in early 2022.

But what exactly is the significance of using drones? "From a ground-level angle, it is impossible to gauge spatial relationships between individuals, and human observers can only watch one or two animals at a time," explains electrical engineer Koger. "By combining both these data streams, we can answer questions about the role of individual decision-making in directing collective foraging and movement in ways that were not previously possible."

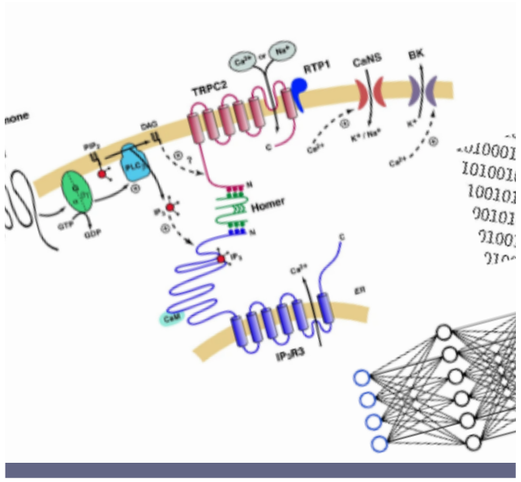


Building up a database for data on collective behaviour in wild primate groups

Behavioural ecologist and biological anthropologist Urs Kalbitzer is setting up a database with long-term behavioural and ecological data from a social primate, the red colobus. He says: “The database will be essential for the efficient investigation of the behavioural ecology and collective behaviour of this and potentially other social primate species in Kibale National Park, Uganda.” Within the project *Leveraging long-term data to investigate ecological drivers of individual and collective behaviour in wild primate groups*, Kalbitzer will transfer the data into a custom-made, easily accessible database on GitHub. “This will significantly facilitate future projects on collective movement, foraging decisions and social behaviour of red colobus and other primates in their natural environment in Kibale,” says Kalbitzer. In addition to construction of the database, Martin Golooba, from Makerere University in Uganda, has started data collection in the field in Kibale to extend the database. However, this work is just getting started. The aim is to collaborate with researchers from different disciplines, such as computer science, nutritional ecology, behavioural ecology and psychology, by addressing theoretical questions from different perspectives and applying appropriate methods.

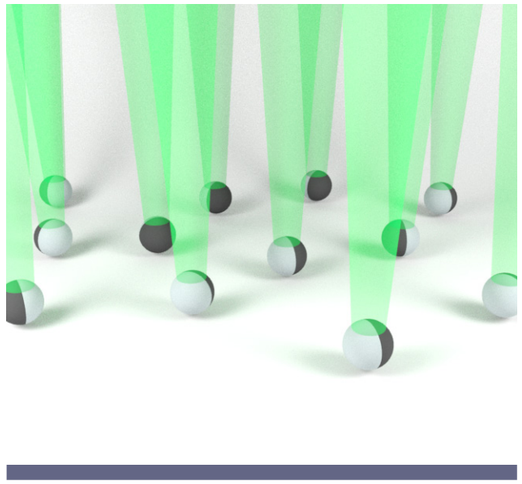
A software framework for multisensory environments

Hemal Naik, computer scientist, has designed a software framework to process the data produced by the motion capture system at the Imaging Barn. The software acts as a communicator between the multimodal measurement system and the researchers. He explains: “It has primary functions to read, manipulate and restructure the 3D measurement data in order to do computer vision, machine learning, closed-loop experiments or statistical data analysis.” To make it easily accessible for researchers from other fields such as biology and psychology, the software is written in Python. The code is provided with multiple example cases that allow users to learn different features of the system. “The idea is to develop the framework further and add more methods that are currently being developed through ongoing projects,” says Naik. For him, the most exciting part was exploring different aspects of the motion capture technology in detail. He says: “Once the framework is polished, it could be a handy tool for many researchers. Most importantly, they will not have to reinvent the wheel every time they start a new project.”



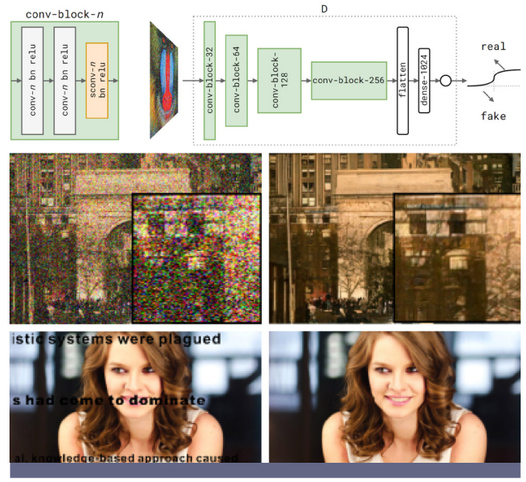
Deep reductions for modelling collectives

Tatjana Petrov and her team have explored how deep learning can facilitate model reduction for high-dimensional stochastic reaction networks. This is an important challenge in modelling dynamic systems where concurrency and stochasticity play a role. “While the idea of emulating complex stochastic processes with deep learning was not entirely new, we – for the first time – proposed how to further automate deep abstractions for stochastic Chemical Reaction Networks (CRNs) by learning the neural network architecture along with learning the transition kernel of the stochastic process,” explains Petrov. The method is applicable to any given CRN, time-saving for deep learning experts and crucial for non-specialists. We demonstrate performance over a number of CRNs with multi-modal phenotypes and a multi-scale scenario where CRNs interact across a spatial grid. The computer scientist says: “The reduction power is impressive and has the potential to break the complexity barriers that were a burden to new discoveries in systems and synthetic biology for a long time.”



Collective behaviour of active collodial particles via reinforcement learning

Using reinforcement learning, the project *collective behaviour of active collodial particles via reinforcement learning* aims to investigate the individual interaction rules in multi-agent systems which lead to desired collective and emergent behaviour. This is done both in simulations and in experiments. The starting point was a system of active microparticles resembling a group of animals or intelligent microrobots. A feedback loop determines the next movement of each particle using a reinforcement learning algorithm. “In most studies, the interplay of individual and collective behaviour is investigated by imposing a certain rule and then investigating the resulting group behaviour. In this project, we go the other way around and introduce the more direct approach of inferring individual rules from a desired behaviour at group level via machine learning,” says physicist Clemens Bechinger.



Deep learning of priors for Bayesian inverse problems in image analysis

Computer scientist Bastian Goldlücke and mathematician Stefan Volkwein have been working on algorithms for deep learning. At first, they worked with imaging, where an image restoration or reconstruction problem is replaced with deep neural networks trained (unsupervised) on the respective distributions. They then focused on how deep learning methods can be successfully combined with partial differential equations (PDE) to solve constrained optimization problems.

Goldlücke says: “We observed that these classes of problems are highly relevant in real applications, including pandemics and electromobility, where networks consisting of different models have to be optimized, but the parameters of the models are uncertain.” Moving forward, they are interested in developing their research into teaching content and working on new methods for research within the cluster.

CULTURE OF COLLABORATION

→

CASCB Seminar Series

A cornerstone of our centre's programme, our weekly seminar series invites speakers locally and from around the globe to present a one-hour talk and engage more deeply with our members in meetings and social events afterwards. In line with our mission to foster a culture of open science and promote the science of collective behaviour in the broader community, CASCB seminars are recorded and made freely available on our website and streaming channel.

Youtube Channel
Collective Behaviour

25.01.2021

Veronika Engert

The physiological resonance of psycho-social stress

Empathy means physiologically resonating the emotions of the people around us, including stress. Empathic stress, therefore, increases the risk of stress-related disorders and stress system dysfunction in those close to chronically stressed people. A highly efficient way to address the effects of both direct and empathic stress is compassion-based mental training, where empathy, compassion and prosocial motivation exercises are practised.

01.02.2021

Lisa O'Bryan

Communication and collective behaviour in non-human and human social groups

Vocal communication is an important component for understanding patterns of collective behaviour both in human and non-human groups.

08.02.2021

Tanya Berger-Wolf

Data science for ecology and conservation

Computational approaches are predictive and descriptive models that provide the ability to increase the quantity and quality of data in the scientific process.

15.02.2021

Elizabeth Hobson

The evolution of decision-making, social cognition and complex sociality

Understanding how much individuals "know" about their social worlds is critical to also understanding the effect of social information on individual behaviour within conflict. Using new computational approaches, which can detect the presence and use of information, has the potential to provide rigorous evidence for the evolutionary patterns underlying social cognition.

19.04.2021

Morgane Nouvian

Social regulation of stinging behaviour in honeybees

To balance between efficient defence and workforce depletion, mass stinging in bees is highly regulated. As a result, recruitment by their sting alarm pheromone and stinging behaviour are finely tuned by their social context.

26.04.2021

Fumihiro Kano

Using cutting-edge technologies to reveal the animal mind

Cutting-edge technologies are useful tools for studying subtle cues in collective behaviour, such as eye-tracking and motion capture to observe the direction of attention and to better explain social interactions in human and non-human groups.

03.05.2021

Gabriella Gall

Group coordination through vocal communication

Meerkats' communication mechanism to maintain group coordination involves adjusting their behaviour (spacing and vocal signals) to cope with changes in the environment, such as dry and wet conditions.

10.05.2021

Shannon Algar

Reservoir computing for swarming individuals and swarming groups

Reservoir computing (an artificial neural network) can be used to understand swarms, but swarms can also be used to understand the constraints and performance ability of reservoirs.

07.06.2021

David Bierbach

How clonal fish and biomimetic robots help us answer fundamental questions in behavioural research

Clonal fish reared under standardized conditions revealed that individual behavioural variation is present early on during embryonic development. The biomimetic fish robot, RoboFish, is based on real-time tracking of shoaling fish, and it is a useful tool for studying the causes and consequences of these individual differences and for investigating questions regarding collective decision-making.

14.06.2021

Brendan Barrett
Wataru Toyokawa

Understanding decision-making and cultural transmissions through a social reinforcement learning framework

Reinforcement learning is a mathematical model of repeated decision-making based on trial-and-error learning that can help identify individual behaviour strategies and individual variations within the population. It considers individual learning, individual reinforcement learning and social learning in individuals, providing a useful tool for studying dynamic processes of behavioural science, such as collective decision-making & cultural transmission.

21.06.2021

Divya Ramesh

Neurochemical signatures in social insect behaviour: what mass spectrometry can tell us

Mass spectrometry is a highly specific and sensitive compound detection technique that can profile and quantify thousands of compounds from a single sample. It can be used with different model organisms to quantify neurochemicals in the brain that represent the behavioural or physiological state of individual organisms, and it is, therefore, an ideal tool for studying individual variation in the social behaviour of social insects.

28.06.2021

Edward Hurme

Continental-scale monitoring of Africa's most gregarious fruit bat groups

Straw-coloured fruit bats (Eidolon helvum), Africa's most gregarious fruit bat and a key seed disperser, migrate and form large seasonal colonies throughout much of sub-Saharan Africa. But the mechanisms and route of migration remain unclear. Hurme presented an analysis of monthly colony counts and a preliminary analysis of individual tracking to explore hypotheses for the mechanisms and drivers of migration.

05.07.202

Sabine Storandt

Graph algorithms for movement data processing

Graph algorithms are efficient methods for indexing, querying, analyzing and visualizing movement data. With proper temporal and spatial indexing, trajectories intersecting a given space-time cube can be reported within a few microseconds and provide data structures that allow for real-time movement projection on interactive maps, which enables applications such as trajectory clustering and pattern analysis.

12.07.2021

Krizler C. Tanalgo
Vishwanath Varma

"Joint Session" Scanning the global underground horizon – understanding priorities for cave-dwelling bats in a changing world

Cave-dwelling bats face multiple threats in multiple dimensions and are highly dependent on their cave and underground habitats for survival. Global and equitable collaboration and open sharing of information are needed for deciding on effective and standardized priorities for bat conservation. To support these efforts, we created the Bat Cave Vulnerability Index, an open and accessible tool that integrates species diversity, landscape features and risk of threats to identify important caves for conservation priority.

12.07.2021

Krizler C. Tanalgo
Vishwanath Varma

"Joint Session" Behavioural variation and coordination among individuals in groups

Animals exhibit individual variation in behaviour and can be modified depending on their social environment. Individual fish can learn spatial features in their habitat but can modulate their behavioural traits by using cues from other individuals to navigate, resulting in highly coordinated and exploratory pairs of fish performing better at spatial navigation. However, pairs show consistency in cohesion while individuals show consistency in exploratory tendency.

07.11.2021

Patrick Müller

Self-organizing patterns in embryos

Self-organizing patterns are ubiquitous in nature and strikingly similar across orders of magnitude – from the molecular arrangements in crystals and snowflakes to the dynamics of societies and the formation of galaxies. Müller presented recent work to elucidate the dynamics and mechanisms underlying this spontaneous symmetry breaking and discussed how we can apply our insights to engineer artificial multicellular self-organizing patterns.

15.11.2021

Bigna Lenggenhager

How bodies shape cognition and behaviour

Important mutual interactions exist between our sense of the body and emotional and cognitive processing. In her talk, Lenggenhager presented research on experimentally induced alterations of the sense of the body and discussed its role in the study of brain-body communication, embodied cognition and behaviour.

22.11.2021

Ahmed El Hady

Integration: from trained to natural behaviours

To survive in an uncertain and dynamic environment, animals need to integrate the relevant information in their environment. El Hady showed that it is possible to train rats to integrate in a dynamic environment where the statistics of the sensory environment are controlled and to obtain insights into the neural mechanisms underlying changes of mind.

29.11.2021

Katrin Vogt

The neural circuits underlying decision-making in Drosophila larvae

How does the brain integrate multi-sensory and state-dependent information in different contexts to modulate stimulus processing and inform decision-making? Working with Drosophila larva and their rich genetic toolkit allows the visualization and manipulation of anatomically well-known cell types in the brain, as Vogt demonstrated.

20.12.2021

Tobias Sutter

Sutter gave an overview of various problems at the intersection of dynamic systems, learning and control. One such problem is inverse reinforcement learning, which basically aims to explain observed behaviour (e.g. of an animal or human) by inferring the underlying cost function describing the observed behaviour as a Markov Decision Process.

(How) is synchrony influenced by STRESS?

Cluster Virtual Retreat Week

22–26
March
2021

In early 2021, the COVID-19 pandemic was still stifling public life. Nevertheless, our cluster community yearned for a possibility to meet no matter what, even if that meant conducting the entire meeting and all scientific exchange online. We needed to plan an online retreat. And we did.

It soon became clear that nobody wanted to sit through online talks and discussion for more than a few hours. We therefore decided to plan a full retreat week. The objective was to have two-hour talk sessions each day, accompanied by plenty of off-session possibilities for exchange. As a general motto, only talks by early career researchers were invited and preferably ones by those who have been working on one of the original 13 starting or other cluster projects. Newcomers to the cluster were, of course, also warmly welcomed.

One week, 29 presentations and many online get-togethers

The programme for the week included 29 short presentations plus one speakers' plenary session on the first day on CASCB's vision and research landscape. We introduced a theme for each day's presentation session, including "Signalling, social behaviour and herd movement" (Day 1), "Stress, brains and decision-making" (Day 2), "Eat, learn, innovate, migrate" (Day 3), "VR and Collective Sensing" (Day 4) and "Measuring, analyzing, visualizing and modelling collective behaviour" (Day 5).

Between and after the sessions, the organizing team had the opportunity to experiment with different tools for bringing people together – be it through randomly mixed "Meet and Greet" breakout rooms or a designated off-session meeting room. Results and feedback on these approaches were mixed too, yet highly appreciated by those who had felt there had been a lack of opportunity to just chat and get together.

Despite – or maybe even due to – the online format attendance during the official sessions was higher even than during our seminar talks with the highest level of attendance. It was fascinating to see how each session had its own composition of people and discussions, although a large "cluster core" seemed to be present at all times. Even more impressive was the range of topics and exciting results, all of which were presented exclusively by CASCB's doctoral students and postdoctoral researchers. Presentations throughout were of high quality and made us shine with pride at what our young researchers had accomplished.

Awards for the most creative presentations

However, the overall excellence of all the talks also made it hard to select a favourite on the basis of scientific content alone. The jury therefore wisely decided to base its selection of the best talks on a less serious yet still competitive enough criterion – namely creativity of format. Within this framework, three presentations stood out: One was Bernadette Denk's beautifully composed presentation on "Stress and Synchrony in Groups" for its truly artisan drawings by hand. Another was Dennis Horvarth's talk on "Stress in Nice Mice" for depicting a captivating sense of humour in the face of non-compliance in – actually very cute – experimental rodents. Last but not least, the locust project group's joint presentation, despite its complexity simply named "Understanding Locusts", was nominated for its masterful network visualization and coherence of multiple-aspect content, which rendered their presentation a shining example of a successful transdisciplinary inter-group effort. The winners graciously accepted the nomination and promised to share the prize (a coupon for one of Konstanz's best ice cream parlours) with their colleagues.

Those who could not attend all sessions could take consolation in the fact that talks were recorded and made available after the retreat.

Meeting of the General Assembly

After the successful wrap-up of a fun and enriching retreat week, we found ourselves much more informed and somehow connected with the community too, despite the physical distance. The event closed with a meeting of the General Assembly and saying farewell to a retiring speaker (Urs Fischbacher), the election of a new speaker (Wolfgang Gaissmaier) as well as the re-election of two previous board members (Tatjana Petrov, Britta Renner) and the election of three new ones (Clemens Bechinger, Einat Couzin-Fuchs, Alex Jordan).

CASCB Conferences

TEDxKonstanz

“Kaleidoscope: Patterns in Nature and Society”

Exploring shifting patterns in nature and society from remarkable perspectives was the aim of the TEDx conference organized by young researchers from the University of Konstanz, the Centre for the Advanced Study of Collective Behaviour and the Max Planck Institute of Animal Behavior (MPI-AB). TEDx events bring together people with different backgrounds to share experiences in specific topics. Nine artists, photographers, musicians, coders and scientists presented their work, with the challenge of doing so in under 18 minutes.

“I’m fascinated by patterns and I find beauty in geometrical order, shapes and structures in nature,” says Angela Albi, co-lead organizer of the conference. “Movement and patterns are also key to what I’m studying for my PhD, animal collective behaviour.” For her, therefore, the conference topic was an obvious choice. A Russian software engineer who uses AI to create artworks (Helena Sarin), a Spanish photographer who transforms ordinary bird flight into otherworldly forms (Xavi Bou) and a US-American engineer who applies the rules of animal swarms to human dancers (Naomi Leonard) were among the global experts who stepped up to the microphone at TEDxKonstanz to present their twist on the study of patterns.

The line-up also included plenty of local talents from academic institutions in the region, including Liat Graver, a contemporary artist from Berlin who uses a robot as a tool for artistic creation, and mathematician Jürgen Richter-Gebert (Technical University of Munich), who uses mathematics to visualize the geometry of music. From Konstanz, Hubl Greiner, musician and composer, and Sudanese drummer Mohammed Badawi exchanged ideas and shared stories of how they use music to build bridges across cultures. From Konstanz universities, economist Anke Hoeffler (University of Konstanz) discussed her work on interpersonal violence in a session with economist Maike Sippel (HTWG), who is studying climate change.

“Science is much more than just a cliché of dusty facts and data sets. It can actually be transferred and transformed into something creative and more tangible, highlighting the beauty of it in a way that creates a bridge for people, arousing their interest and curiosity, wanting to discover science, learn more and broaden or gain (new) perspectives,” says Jana Straßheim, the event’s Communication Manager. “The same goes for art – art is much more than this cliché of something subjectively beautiful but rather ‘useless’. Bringing both together seemed to be a perfect fit for science and art communication.”

All talks are available online:
tedxkonstanz.com/talks-2021

4th Annual ESLR Workshop
Tracing Transmission From Nodes to Networks

Sonja Wild and Michael Chimento organized the virtual workshop Tracing Transmission – from Nodes to Networks within the Association of Early-career Social Learning Researchers (ESLR). They provided some insight into the event and their experience of bringing people together online.

You organized a four-day workshop on Tracing Transmission – from Nodes to Networks. What is it about this topic that interests you?

Sonja My entire career so far has focused on questions revolving around drivers that lead to behavioural diversity and the emergence of culture in wild animal populations. Behavioural patterns in wild animals can be challenging to study, but recent advances in technology and the development of novel statistical methods have opened up exciting new avenues to approach these questions. How does the social network shape the transmission of novel behaviour? What learning strategies do individuals employ and why? How do these change throughout an individual's lifetime and in relation to the environment? And what lessons can we learn from all this for conservation?

Michael My area of research focuses on cultural evolution, or how cultural traits and their distributions change over time. Cultural traits are socially transmitted from individual to individual across association networks, so questions such as when, how and why social transmission occurs between individuals are very relevant for progressing our understanding of why certain cultural traits persist and others die out. Developing models for transmission processes is still an area of active exploration and debate in the field, so organizing a workshop centred on this topic seemed useful, especially for early career researchers who are beginning to apply these methods to their own data.

Concerning collective behaviour – what were the three most relevant outcomes of the workshop?

Michael & Sonja This year's workshop focused on the theme of social networks. One keystone event was a hands-on workshop on applying Network-Based Diffusion Analysis (NBDA) models, which serve to detect signals of social learning within networks of individuals. NBDA is a popular and powerful tool for detecting and quantifying social learning and for establishing typical pathways of transmission, thereby helping to understand how learning processes can shape behavioural patterns on a population level. During a hands-on and interactive workshop, participants learned to understand the theoretical background of NBDA models and how to implement them.

The second key activity was a workshop on data visualization. In times of automated data collection, researchers often generate large, complex and sometimes high-dimensional data sets, which can be challenging to present to an audience. Participants learned new creative skills related to visualizing and presenting data generated by analyses of social networks and agent-based models.

Finally, during the two exciting keynote talks by Dr Helge Giese (CASCB) and Dr Barbara Klump (MPI), and of course the numerous talks and posters from participants, we learned so much about collective behaviour across a wide range of different species and contexts. Did you know that in tits, individuals with higher activity levels are more likely to be the leaders in a social group? Or that in humans, ethnocentrism is highest in conditions of low to moderate threat, while they start cooperating across groups when facing higher levels of threat?

ESLR workshops also aim to bring early career researchers together. What did you implement for virtual networking with the other participants? And how was it perceived by the participants?

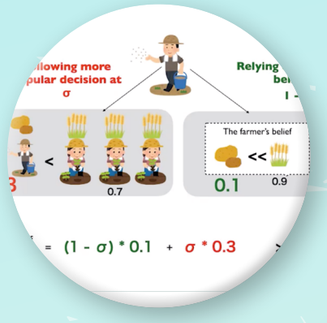
Michael & Sonja The ESLR workshop brought together over 60 participants from 10 different time zones. We chose to host the event on the GatherTown platform, which allows participants to explore a virtual world that we constructed using an avatar and lent a little interactivity and realism beyond what a virtual workshop held strictly over Zoom would offer. We prepared a variety of activities to enable networking among participants. This included an icebreaker, during which we created mind maps to identify overlaps and differences in research interests, and a guided discussion on challenges we face as early career researchers. We provided private and group spaces in the virtual venue to encourage after-hour drinks/chats, and we put up a networking board, on which participants could leave their contact details to stay in touch even after the event. Overall, we believe we have managed to encourage exchange and potential future collaborations among like-minded early career researchers.

What was your highlight when organizing the workshop?

Sonja Organizing a virtual workshop was a huge challenge. My personal highlight was seeing all the content faces – both of the participants and the organizing team – at the end of the workshop week. Finishing the week with a smile on my face after all the hard work we put in felt pretty good!

Michael One highlight for me was designing the venue space in GatherTown. I didn't want to use the generic templates for rooms and put quite a bit of effort into making the space inviting so that participants would feel comfortable and part of it. Seeing how much participants had enjoyed the workshop was very rewarding.

eslrsociety.org/events/4th-annual-workshop
twitter.com/konstanz2021



IC2S2 2021
Satellite Symposium Collective Behaviour

What can research on human and non-human animals learn from each other?

CASCB hosted the IC2S2 Satellite Symposium Collective Behaviour in July 2021 to build a bridge between the computational social sciences community and the collective behaviour community. The aim was to draw connections between fundamental mechanisms of behaviour in human and non-human animals.

Among other researchers, three CASCB members presented their latest work: Ariana Strandburg-Peshkin talked about communication and coordination in collectives, using meerkats as her research species. Helge Giese highlighted how experimental paradigms can be used as a model to understand opinion dynamics in groups and Wataru Toyokawa showed how human collective decision-making can be made understandable by using a reinforcement learning framework.

"We succeeded in bringing together a remarkable group of outstanding early career researchers who presented their exciting research along those lines," says CASCB co-speaker Wolfgang Gaissmaier, who hosted the symposium. The connections with each other and the audience were discussed in a panel discussion at the end of the session.

exc.uni-konstanz.de/collective-behaviour/news-and-events/upcoming-events/satellite-symposium

Courses and Collaborations

Bayesian data analysis for biological and behavioural scientists

Brendan Barrett and Urs Kalbitzer are running a Bayesian Data Analysis course for beginners and intermediates in the 2021/22 winter semester. Participants learn about the theoretical and practical foundations of Bayesian statistical inference. They use various types of linear models, causal inference and the production of reproducible workflows.

Brainstorming 25

Brainstorming 25 was organized in early 2021 as a platform to discuss out-of-the-box ideas, such as experiments with animals in zero gravity. The aim was to reduce the knowledge gap between core groups in the cluster. Researchers presented their ideas in five minutes and were given feedback from an interdisciplinary audience in 20 minutes. Organizer Hemal Naik says: “We focused on a wide range of topics from VR/AR experiments with animals to measuring 3D motion of bats in the wild. The 4Ps of science, PhDs, Postdocs, PIs and Professors, took part and some had the opportunity to initiate successful collaborations.” The 25-minute format was chosen to replicate coffee table discussions: “short enough to boost creativity and long enough to gain a short overview of the idea,” as Naik states.

University of Essex and University of Konstanz research workshop on collective behaviour

In collaboration with members of the Centre for the Advanced Study of Collective Behaviour (Konstanz, Germany; YERUN), the University of Essex hosted a cross-university research workshop in September 2021. The workshop explored collaboration opportunities in the field of collective systems, with a focus on both animal and human social behaviour, including animal-human interactions. Experimental, observational, theoretical, analytical and computational approaches were covered. A follow-up workshop in Konstanz is planned for 2022.

Diversity and Inclusion

Diversity and equity in a year full of challenges and opportunities

Our cluster welcomes knowledge, expertise and collaboration from around the world, and during our work we seek to ensure equity and minimize inequalities wherever we see them. **Our aim is to speak up when we see injustices** and amplify those voices which are often overheard. This allows us to build a diverse environment where everybody feels **welcomed**, **respected** and **appreciated**.

During the last year, filled with challenges and countless opportunities, we focused on the mental well-being of all our members and encouraged the science community within the cluster to become mindful of the circumstances while emphasizing their value to the grand community. Courses on mental health in pandemic times were paramount to ensuring the health of the community in its core and to building a **strong and trusting environment** for all perceptions of reality.

Picturing the future of science for us means fostering and supporting underrepresented groups of scientists in all career stages towards the top. By screening the movie ‘Picture a Scientist’ as well as hosting a follow-up discussion, the cluster community celebrated the **International Women's Day** on 8 March 2021with an inspiring film and the aspiration to diversify science in the near future.

Welcoming and appreciating diversity in our community is a key component of our open house philosophy. To fully understand each other, an introductory course on diversity in teams provided insightful knowledge on the conscious and unconscious mechanism of perception and how experiences and socialization play a major role in valuing our counterparts. In the process, trusting and re-thinking our norms and values in everyday situations will help to amplify our actions and broaden the scope of creative potential.

Alongside measures and activities, the CASCB implemented key elements of structural change such as the dual position of Equal Opportunity Representatives and their rights as voting members of the Executive Board and, therefore, strengthened the voice of all within strategic decision-making processes in the cluster.

The elected Equal Opportunity Representatives alongside the Diversity Officer and volunteers from the cluster community form the **Diversity Board**. This committee investigates which structural improvements in areas such as the recruitment process, field work or summer and winter schools in the Global South can be implemented and are of interest to the science community.

This year in particular was filled with challenges of many kinds. However, opportunities like the Big Chunk Call for new, large-scale research projects offered resources to the community, which will shape the cluster’s research future tremendously. To learn more about the scientist’s impact on diversity community-wide, the diversity statements offered countless amazing and impressive insights into how research on collective behaviour will shape the diversity team’s work in the future.

Outreach

Hegau Bodensee Seminar

"University Day" is a fixed part of the Hegau-Bodensee Seminar, which gives students from the Alexander-von-Humboldt-Gymnasium, a high school in Konstanz, the opportunity to conduct research directly with scientists and to experience hands-on recent research work at universities. Supported by lectures, workshops and excursions, the students tackle chosen topics in collaborating working groups. In 2021, Armin Bahl, Vivek Sridhar and Mariam Mahmoud from the cluster participated in the seminar.

In Armin Bahl's workshop, they looked at an image dataset and used microscopy techniques in the lab to characterize the activity of thousands of neurons in the brain of larval zebrafish. In the second workshop, Vivek Sridhar and Mariam Mahmoud introduced the pupils to virtual reality (VR) and showed how VR can be used to reveal rules that govern locust plagues.

Britta Renner Sustainable food expert

Health psychologist Britta Renner's expertise on the subject of sustainable food is in great demand. She was one of the authors of a position paper by the Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection (WBAE) of the Federal Ministry of Food and Agriculture (BMEL), June 2020, which in 2021 was also published by the German Nutrition Society (DGE). The vital importance of this topic is exemplified by the statement issued by Udo Di Fabio, former judge of the Federal Constitutional Court, in response to the WBAE's position paper. This triggered a public debate which Britta Renner and her colleagues helped to shape with their reply to Udo Di Fabio. Last but not least, Britta Renner was honoured with an invitation to speak at the UN Food Systems Summit (UN FSS).

"I consider it a success that we have initiated a discussion about creating fair food environments and about rethinking underlying consumer perceptions," says Britta Renner. She would like to see scientific findings taken into account in politics "because in my opinion, an expert opinion from independent scientists, carefully prepared with interdisciplinary expertise, provides an excellent and informed basis for political decisions. However, the independence of research is very important here; the roles of politics and science must remain clearly separated."

Reshaping Nature – how data turn into art

An outreach project between CASCB, MPI-AB and Merz Akademie, Stuttgart

Have you ever wondered if experimental data can be turned into art? The CASCB and the MPI-AB are collaborating with Merz Akademie on a sci-art project called "Reshaping Nature", with a focus on data visualization.

Together with nine students from the Merz Akadmie, members of the CASCB and the MPI-AB are participating in a semester-long course led by Mario Doulis and Jörg Frohnmayer. The idea of the course is to bring young students from arts and design in contact with scientists working at the CASCB and the MPI-AB. CASCB member Hemal Naik was responsible for initiating the project: "For me, art and science represent two sides of the same coin. Artists and scientists have much to learn from each other's perspectives and methods. We wanted to create a platform for both to interact with each other and work together. This initiative will help both researchers and art students to explore a new perspective or add a new flavour to their own work."

The kick-off event was a two-day visit to the MPI-AB in Möggingen and the University of Konstanz. The focus was on gaining insights into each other's work and establishing contact between Merz students and CASCB and MPI-AB researchers. "This truly is an inspiring approach to have an interdisciplinary exchange" says Jörg Frohnmayer, research associate at the Merz Akademie. He appreciated getting a more detailed insight into a broad variety of research topics because "it encouraged art and design students to dig into "real research data" and it gave researchers an insight into artistic approaches for visualization." His colleague Mario Doulis, professor and head of the New Media Department at the Merz Akademie adds: "I know from my own experience as a design student doing an internship at Fraunhofer IAO how important it is to meet the people you work with in their working environment. During our visit, we could not only talk with the researchers directly about their work, we also got an impression of how a researcher's working day looks. On the one hand, they work on completely different topics as designers or artists, on the other hand they are – what a surprise – people like you and I..."

Artistic twist

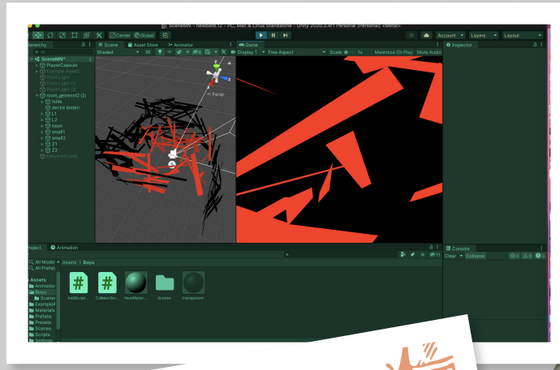
The students are now using datasets from behaviour experiments and are giving the data an artistic twist. They are visualizing, for example, a stork's journey, the mating behaviour of fiddler crabs or the echolocation of bats. The plan is to display the outcome of their work in an art exhibition at the VCC in February 2022. MPI-AB postdoctoral researcher Daniela Perez thinks that "widely sharing scientific discoveries and data is a central, if not the most important, part of science." She shared her fiddler crab data because "the opportunity to get my science portrayed by artists is just too good to miss." She is excited to see what these young inspiring artists will create with her fiddler crab data. She says: "I spent almost ten years studying fiddler crabs, and now I am transitioning to worms. This partnership with Merz Akademie will be a beautiful tribute to all those years dedicated to fiddler crab research."

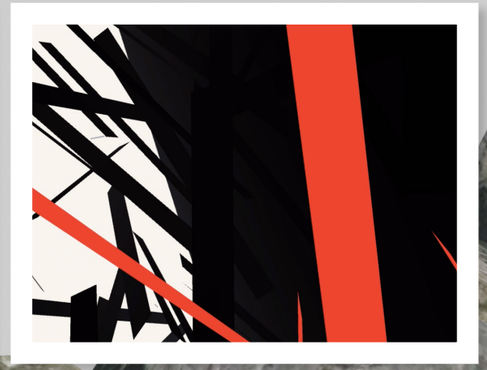
How the collaboration came about

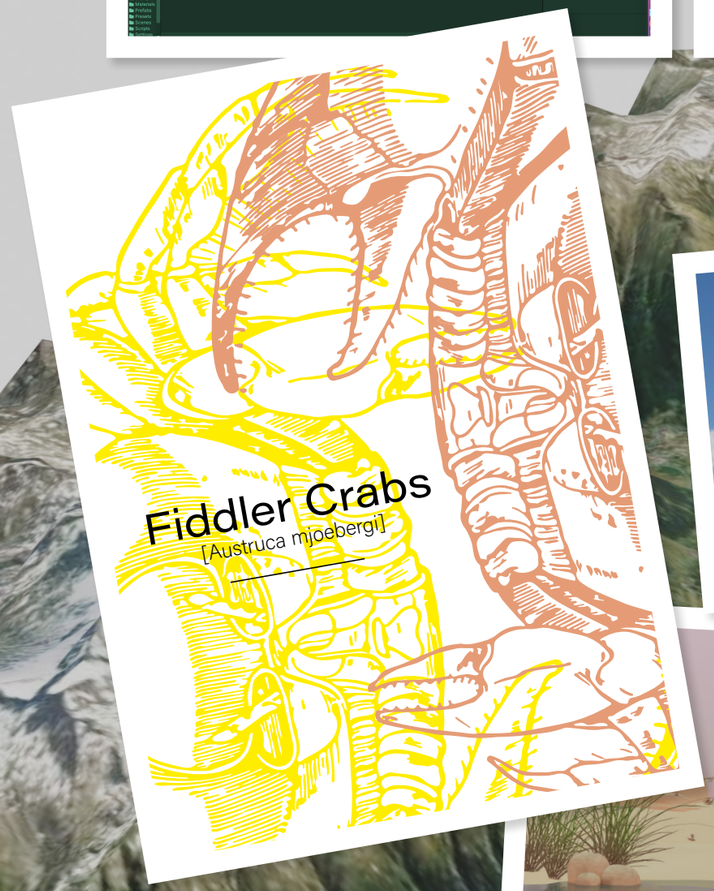
The collaboration began with a coincidental meeting between Hemal Naik and Maren Schmol, director of the Merz Akademie, in India. Naik suggested the idea of collaborating with art institutes or artists in order to create sustainable outreach programmes for science communication. The idea was presented to Frohnmayer and Doulis at the Merz Akademie as well as several members of the University of Konstanz and the MPI-AB (including Falk Schreiber and Martin Wikelski) during a brainstorming meeting in the summer of 2019. Having gained initial support, Naik and Frohnmayer decided to work together and organized three courses between 2019 and 2020 to test the feasibility of such collaborations. "Several members of the MPI-AB and the CASCB showed interest and shared their data and insights," says Naik. "Finally, in 2021 we decided to go beyond concept and prototype development. That is why we are now organizing the course with the concrete plan of setting up exhibitions of the artwork at the VCC."

Merz Akademie

Hochschule für Gestaltung, Kunst und Medien, Stuttgart staatlich anerkannt







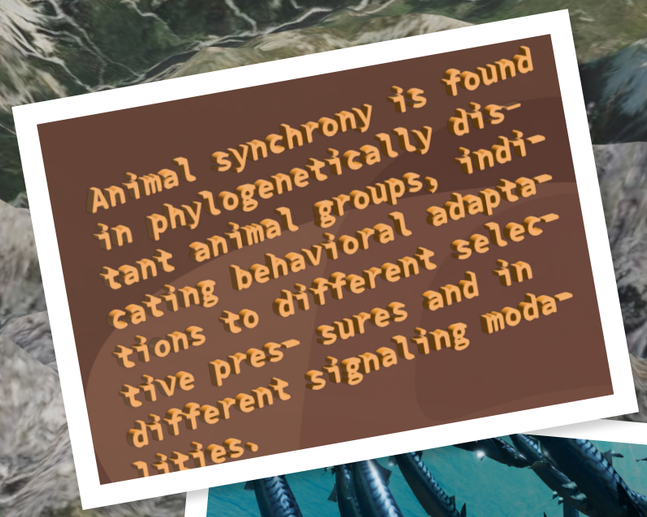
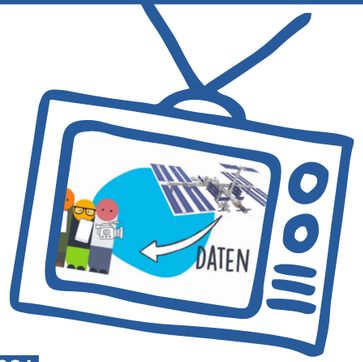


Photo exhibition by Christian Ziegler in the VCC

Have you ever seen the world's largest bat swarm in Zambia? Or an ochroma tree full of bees in Panama? What about bonobos in the wild? If you answered even just one of these questions with "No", then you probably haven't been to the cluster's new floor yet. Thirteen fascinating photographs related to collective behaviour have been on display in the corridor there since November 2021. The photos were taken by Christian Ziegler, an outstanding photojournalist and filmmaker specializing in science-related topics. He works as an outreach photographer for the Max Planck Institute of Animal Behaviour in Konstanz. For many CASCB projects too, we have been lucky enough to have him accompany our researchers with his camera. Ziegler is a regular contributor to National Geographic, and his work has also been widely published in other magazines, such as GEO. His aim is to highlight species and ecosystems under threat and to share their beauty and importance with a broad audience. The CASCB speakers and office team chose photos which are related to the cluster projects and show collective behaviour in a variety of ways.

Visit the photo exhibition
Zt 9 in the VCC

CASCB in the media selection



logo! / 13.9.2021

Das Icarus-Projekt

logo!, a children's news channel, explained how animals throughout the world are studied using a small backpack and a large space station. Does this sound familiar to you? If it dies it is because it was the ICARUS project which was explained to the children.

SWR / Landesschau Baden-Württemberg
21.6.2021

Dr. Dina Dechmann und Lara Keicher sind von Fledermäusen fasziniert

Why are bats so fascinating? SWR Landesschau Baden-Württemberg, a German broadcasting company, asked CASCB researcher Dina Dechmann and her colleague Lara Keicher from the MPI-AB this questions. During the 12-minute TV interview they delivered fascinating insights into their research.

swrfernsehen.de

SWR / Die Tierforscher vom Bodensee
7.6.2021

Die Imaging Scheune

The Imaging Barn in Möggingen is used for many research projects. The technique is incredible, thought local TV channel SWR. That is why it presented our Imaging Barn in a five-minute report.

swrfernsehen.de


SALEM/UHLDINGEN-MÜHLHOFEN 28. Juli 2021, 09:01 Uhr

Der SÜDKURIER-Storch heißt Sunny: Mühlhofer Kindergartenkinder siegen bei Namenswettbewerb

Das Kinderhaus Sonnenschein aus Mühlhofen ist Namensgeber für den SÜDKURIER-Storch. Die Kinder gewannen den Wettbewerb aufgrund ihres besonderen Bildes und der Begründung für den Namensvorschlag Sunny. Auch ein Sonderpreis wurde vergeben.

A Series about our stork project in the local newspaper. CASCB member Andrea Flack was responsible for initiating the tagging project. Readers of the local newspaper followed the stork's flight south. At the same time, readers discovered which new insights the scientist gain from tagging storks.

Südkurier / 20.6.2021

Jungstörche vom Affenberg fliegen im Herbst mit einem Sender huckepack in den Süden

suedkurier.de

Südkurier / 28.7.2021

Der SÜDKURIER-Storch heißt Sunny. Mühlhofer Kindergartenkinder siegen bei Namenswettbewerb

suedkurier.de

Südkurier / 04.9.2021

SÜDKURIER-Storch Sunny fliegt jetzt der Sonne entgegen – momentan gefällt es ihm in Katalonien

suedkurier.de

Südkurier / 23.10.2021

Ein Minimalist in Katalonien: SÜDKURIER-Storch Sunny denkt gar nicht daran, bis nach Marokko zu fliegen

suedkurier.de

Gottfried Wilhelm Leibniz Prize

for Iain Couzin

Outstanding research on the "rules of the swarm": behavioural biologist Professor Iain Couzin from the University of Konstanz has received the Gottfried Wilhelm Leibniz Prize of the German Research Foundation (DFG). The Leibniz Prize, which is awarded by the German Research Foundation (DFG), is the most important and most highly endowed research award in Germany.

His name is inextricably linked with the study of collective behaviour and swarm intelligence. He uses computer vision and sophisticated tracking methods to observe the decision-making behaviour of thousands of animals simultaneously and to investigate the "rules of the swarm". Now, Konstanz behavioural biologist Professor Iain Couzin has been awarded the Gottfried Wilhelm Leibniz Prize 2022. The German Research Foundation (DFG) announced its decision on Thursday, 9 December 2021. Iain Couzin is Professor of Biodiversity and Collective Behaviour at the University of Konstanz and Director of the Max Planck Institute for Animal Behavior. He is also the co-speaker of the Cluster of Excellence “Centre for the Advanced Study of Collective Behaviour” at the University of Konstanz.

“A flock of thousands of birds changes its direction of flight in a fraction of a second to avoid a bird of prey. The flock moves in a billowing cloud as if it were a single organism,” Iain Couzin explains his research interest. “What rules do the individuals in the collective follow to coordinate with countless others with such precision? Is there such a thing as a ‘collective mind’? How can we succeed in studying this swarm behaviour if we have to measure the behaviour of hundreds, or thousands, of animals at the same time?”

A pioneer of modern, quantitative behavioural biology

Iain Couzin's goal is to understand collective intelligence and examine the underlying mechanisms. He uses cameras, drones, GPS and motion sensors to record the behaviour of animals in swarms. To analyze the huge amounts of data, he and his team have developed computational algorithms that can calculate the movements and even the fields of vision of hundreds of individual animals in real time. This allows him to understand how information spreads in the swarm and how the individuals influence each other in their movements. In this way, Couzin was able to show that universal principles underlie collective decision-making in nature.

With his development and use of new technologies, Iain Couzin has become a pioneer in modern, quantitative behavioural biology and is known for his use of virtual reality to study animal behaviour. Individual animals are placed in ‘holographic' immersive virtual environments using photorealistic digital projections, in which the researcher can precisely control environmental factors – from the nature of the landscape, to the movements of the virtual members of the swarm and the simulation of an attack by a predator. By controlling these factors, Couzin can precisely test the behaviour of the real animal. This allows him to understand how animals sense their world, and how the interactions of the individual animals lead to the complex behaviour of the swarm.

An extraordinary researcher and independent thinker

“Iain Couzin is an extraordinary researcher, a truly autonomous and independent thinker. He sees the study of collective behaviour as an intrinsically interdisciplinary research field," says Professor Katharina Holzinger, rector of the University of Konstanz. “Iain is also an exceptional team player. With his fascination for behavioural research and his openness to interdisciplinary methods, he has succeeded in bringing together internationally leading researchers from the fields of biology, computer science, particle physics, psychology, economics and social sciences in Konstanz. We are proud to have Iain Couzin as one of the key persons at our cutting-edge research centre in the field of collective behaviour, the Cluster of Excellence ‘Centre for the Advanced Study of Collective Behaviour’.”

Iain Couzin continues to drive the development of new research methods and technology, from innovative tracking techniques to computer modelling and computer vision. Recently in 2021, the new research building, Centre for Visual Computing of Collectives (VCC), was opened at the University of Konstanz. It was built with funding from the federal government, the Federal State of Baden Württemberg and the Hector Foundation II. The building offers research technology that is unique worldwide, such as the Imaging Hangar. In this hall, which is equipped with the latest projection and tracking technology, entire animal swarms will soon be placed in virtual environments in order to research the rules of the swarm.

“Collective behaviour is a young and very dynamic field of research. I am thrilled that the work of my remarkable group has been recognized in this way. Being awarded the Gottfried Wilhelm Leibniz Prize is a deep honour. I thank the German Research Foundation for this high distinction,” says Iain Couzin.

The Gottfried Wilhelm Leibniz Prize, considered the most important German research prize, is awarded annually by the German Research Foundation and endowed with up to 2.5 million euros.

PERSONNEL →

Members

Collective behaviour in Konstanz is transdisciplinary at its core. Our community is made up of researchers from seven disciplines — biology, computer science, economics, psychology, maths, physics and sociology — and from two institutions — the University of Konstanz and the Max Planck Institute of Animal Behavior. What unites us is our drive to move beyond the boundaries of disciplines in order to collaborate on our shared interest: studying individuals in the context of who they influence and are influenced by, and harnessing tools to process, analyze and visualize the resulting data.

Clemens Bechinger

CASCB PI,
Physics, Uni Konstanz

Thejasvi Beleyur

CASCB Postdoctoral Researcher, Behavioural Biology, MPI-AB

Michael Berthold

CASCB PI,
Bioinformatics and Data Mining, Uni Konstanz

Felicia Afriyie

Diversity, Equal Opportunity & Career Officer, CASCB

Ellen Aikens

CASCB Postdoctoral Researcher Animal Migration

Lucy Aplin

CASCB Group Leader Cognitive Ecology, MPI-AB

Elisabeth Böker

Communication Officer, CASCB

Johann Bornholdt

CASCB Doctoral Student, Computer and Information Science

Aneesh Bose

CASCB Postdoctoral Researcher, MPI-AB

Alisa Auer

Alisa Auer, CASCB Doctoral Network, Biological Work and Health Psychology, Uni Konstanz

Armin Bahl

Emmy Noether Group Leader, CASCB, Neurobiology, Uni Konstanz

Brendan Barrett

CASCB Affiliate, Ecology of Animal Societies, MPI-AB

Hanja Brandl

CASCB Postdoctoral Researcher, MPI-AB

Eren Cakmak

CASCB Doctoral Student, Computer and Information Science

Daniel Calovi

CASCB Postdoctoral Researcher, Collective Behaviour

Max Capelle

CASCB Doctoral Network, Neurobiology, Uni Konstanz

Michael Chimento

CASCB Doctoral Network, IMPRS Doctoral Student, MPI-AB

Blair Costelloe

CASCB Affiliate Collective Behaviour, MPI-AB

Oliver Deussen

CASCB Co-speaker Visual Computing, Uni Konstanz

Serena Ding

CASCB Affiliate, Group Leader, MPI-AB

Fabian Dvorak

CASCB Postdoctoral Researcher, Applied Research in Economics

Iain Couzin

CASCB Co-speaker Collective Behaviour, Uni Konstanz and MPI-AB

Einat Couzin-Fuchs

CASCB Group Leader, Neurobiology, Uni Konstanz

Meg Crofoot

CASCB PI, Ecology of Animal Societies, MPI-AB

Ahmed El Hady

CASCB Postdoctoral Researcher

Stefan Feyer

CASCB Doctoral Student, Computer Science

Urs Fischbacher

CASCB PI Applied Research in Economics, Uni Konstanz

Grace Davis

CASCB Doctoral Network, Ecology of Animal Societies, MPI AB

Dina Dechmann

CASCB PI, Animal Migration, MPI-AB

Bernadette Denk

CASCB Doctoral Student, Clinical Neuropsychology

Andrea Flack

CASCB Group Leader, Animal Migration, MPI-AB

Karl-Philipp Flösch

CASCB Doctoral Student, General and Biological Psychology

Barbara Fruth

CASCB Affiliate, MPI AB

Wolfgang Gaissmaier

CASCB Co-speaker, Social Psychology and Decision Sciences, Uni Konstanz

Giovanni Galizia

CASCB PI, Neurobiology, Uni Konstanz

Gabriella Gall

CASCB Postdoctoral Researcher, Zukunftskolleg Fellow

Helge Giese

CASCB Postdoctoral Researcher, Social Psychology and Decision Sciences, Uni Konstanz

Bastian Goldlücke

CASCB PI, Computer Vision and Image Analysis, Uni Konstanz

Susanne Goldlücke

CASCB PI Microeconomic Theory, Uni Konstanz

Zoe Goldsborough

CASCB Doctoral Network, MPI-AB

Daniela Göpfrich

Administrative Manager, CASCB

Nico Gradwohl

CASCB Postdoctoral Researcher, Social Psychology and Decision Sciences

Michael Griesser

CASCB Affiliate, Biology, Uni Konstanz

Marcus Groettrup

CASCB PI, Immunology, Uni Konstanz

Michael Grossniklaus

CASCB PI, Databases and Information Systems, Uni Konstanz

Mathias Günther

Imaging Facility Management, CASCB

Yannick Günzel

CASCB Doctoral Student, Neurobiology

Thomas Hinz

CASCB PI, Empirical Social Research with a Focus on Survey Research, Uni Konstanz

Dennis Horvath

CASCB Doctoral Student, Biology

Edward Hurme

CASCB Postdoctoral Researcher, Animal Migration

Martin Imhof

CASCB Affiliate, General and Biological Psychology, Uni Konstanz

Alex Jordan

CASCB Group Leader, Collective Behaviour, MPI-AB

Urs Kalbitzer

CASCB Affiliate, Ecology of Animal Societies, MPI-AB

Kavitha Kannan

CASCB Doctoral Network, Neurobiology, Uni Konstanz

Fumihiro Kano

CASCB Junior Group Leader

Daniel Keim

CASCB PI, Data Analysis and Visualisation, Uni Konstanz

Gisela Kopp

CASCB Affiliate, Zukunftskolleg, Uni Konstanz

Matthias Kraus

CASCB Postdoctoral Researcher, Computer Science, Uni Konstanz

Amit Landge

CASCB Doctoral Network, Synthetic and Computational Biology, Uni Konstanz

Mariam Mahmoud

CASCB Doctoral Student, Visual Computing

Tracy Montgomery

CASCB Affiliate, Postdoctoral Researcher, MPI-AB

Mahsa Mozafary

CASCB Doctoral Network, Computer and Information Science, Uni Konstanz

Thomas Müller

CASCB Affiliate, Philosophy, Uni Konstanz

Hemal Naik

CASCB Affiliate, Postdoctoral Researcher, MPI-AB

Morgane Nouvian

CASCB Affiliate, Zukunftskolleg, Uni Konstanz

Paul Nührenberg

CASCB Doctoral Student, MPI-AB

Chase Nuñez

CASCB Affiliate Postdoctoral Researcher, MPI-AB

Felix Oberhauser

CASCB Postdoctoral Researcher, Collective Behaviour

Tatjana Petrov

CASCB Junior Professor, Modeling Complex Self-Organised Systems, Uni Konstanz

Winfried Pohlmeier

CASCB PI,
Economics and Econometrics,
Uni Konstanz

Jens Pruessner

CASCB PI,
Clinical Psychology,
Uni Konstanz

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CASCB Affiliate,
Neurobiology, Uni Konstanz

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CACSB Postdoctoral
Researcher, MPI-AB

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Psychological Assessment and
Health Psychology, Uni Konstanz

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CASCB Affiliate, Alexander von Humboldt Postdoctoral Fellow, MPI-AB

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Researcher, Neurobiology

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CASCB PI, Practical Computer Science with focus on Computational Life Sciences, Uni Konstanz

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Head of General and Biological Psychology, Uni Konstanz

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Jana Straßheim

CASCB Doctoral Student,
Psychology

Eli Strauss

CASCB Affiliate Member, Alexander von Humboldt Postdoctoral Fellow, MPI-AB

Sahra Styger

CASCB Doctoral Network,
Philosophy of Science,
Uni Konstanz

Isaac Kazuo Uyehara

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Katrin Vogt

CASCB Affiliate and Group Leader, Department of Neurobiology, Uni Konstanz

Stefan Volkwein

Professor, Numerics,
Uni Konstanz

Urs Waldmann

CASCB Doctoral Student,
Computer and Information Science

Lisa-Marie Walther

CASCB Doctoral Student, Biological Work and Health Psychology

Anja Weidenmüller

ASCB Postdoctoral Researcher, Neurobiology

Katinka Wendt

Administrative and Finance Officer, CASCB

Martin Wikelski

CASCB PI
Animal Migration, MPI-AB

Alexandra Wild

Science Manager, CASCB

Sonja Wild

CASCB Postdoctoral Researcher, Cognitive Ecology

Petra Wirtz

CASCB PI,
Work and Health Psychology,
Uni Konstanz

Alumni

- Carla Avolio
- Stefan Banholzer
- Kiran Dhanjal-Adams
- Damien Farine
- Hanna Hauptmann
- Daniel Kaping
- Máté Nagy
- Stefan Streuber
- Johanna Stucke
- Stefano Toggnazi

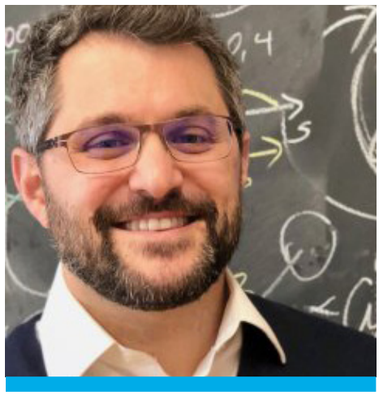
Scientific Advisory Board

The Scientific Advisory Board is a body comprising six internationally renowned experts who advise the cluster's management on scientific, organizational and strategic issues. They are suggested on the basis of their academic expertise and contribution to interdisciplinary research. Upon agreement, they are nominated for three years by the cluster's Executive Board. They represent an extended interdisciplinary scientific community and act as a transdisciplinary forum of experts for the cluster's management. The scientific advisory board meets once a year.

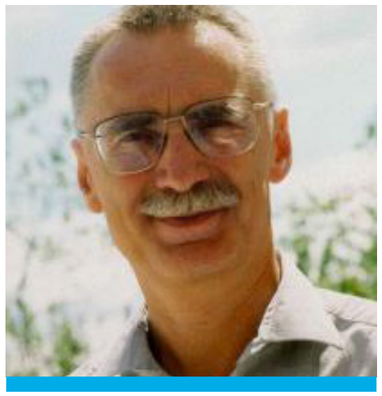
Naomi Leonard
Princeton University,
Computational Mathematics

Leonida Fusani
University of Vienna,
Animal Physiology

Gene Myers
Max Planck Institute of Molecular
Cell Biology and Genetics,
Bioinformatics



Joshua Shaevitz
Princeton University,
Biophysics



Karl Sigmund
University of Vienna,
Game Theory

Jutta Schneider
University of Hamburg,
Animal Behaviour

PhD Students at the CASCB

PhD Network Centre for the Advanced Study of Collective Behaviour

A

Studying individuals in the collective

Katja Slangewal

Having collective discussions about ideas from a variety of perspectives.

Max Capelle

#interdisciplinary #inspiration #beingcollective

Bernadette Denk

#talkingAboutStress #interestingDiscussions #supportNetwork

Jana Straßheim

#SciCom #support #buildingInnovativeScience

Kavitha Kannan

To share ideas and be inspired in an interdisciplinary collective behaviour network.

Dennis Horvath

The interdisciplinarity allows for interesting insights and input for my investigations on immunity and stress.

Michael Chimento

Connecting with great resources and minds across disciplines.

Alisa Auer

#TalkingAboutIndividuals AndCollectives #PhDcollective #Encouragement

Lisa-Marie Walther

#GlimpsesIntoOtherScientificDisciplines #ScientificExchange #Motivation

Mahsa Mozafary

Amit Narendra Landge

#networking #communicatingScience #innovationAndInspiration

Mariam Mahmoud

#CollaborativeTeamWork #GreatDiversity #MakingFriends

Urs Waldmann

#DifferentPointsOfView #IdeasForApplication #RealWorldData

Eren Cakmak

Thinking across different perspectives and disciplines.

Johann Bornholdt

#interdisciplinaryInsights #networkingInterestingPeople #taklingIdeas

Sahra Styger

#interdisciplinary #GreatDiversity #EmpiricalWorkMeetsPhilosophy #CuttingEdgeResearch

B

Aggregation in the collective

Karl-Philipp Flösch

#collectiveIdeas #sharingExpertise #buildingInnovativeScience

Grace Davis

Yannick Günzel

Sharing experiences across a broad spectrum: From scientific hypotheses to mental health problems.

Zoë Goldsborough

Paul Nührenberg

#collaboration #exchange #support

Stefan Feyer

#knowledgeExchange #gettingElaboratedAnswers #awesomeTimesWithAwesomePeople

C

Exploiting computational methods

Major Grants and Awards

AWARDS

Michael Chimento
Best Paper Award from the IMPRS for Organismal Biology for the publication: Chimento M, Alarcón-Nieto G, Aplin LM. Population turnover facilitates cultural selection for efficiency in birds. Current Biology. 2021 Jun 7;31(11):2477-83.

Iain Couzin
Gottfried Wilhelm Leibniz Prize 2022 and Global Highly Cited Researcher 2021, Web of Science Group, Clarivate

Oliver Deussen
Fellow of the Gesellschaft für Informatik (German Informatics Society)

Barbara Fruth
Awards from Centre for Research and Conservation BE, Bonobo Alive e.V., Deutsches Primatenzentrum (DPZ)

Harald Reiterer
Lehrpreis des Landes Baden-Württemberg

Eli Strauss
Alexander von Humboldt Postdoctoral Fellow

Falk Schreiber
Lehrpreis des Landes Baden-Württemberg

Martin Wikelski
Order of Merit of Baden-Württemberg, Award from Gordon and Betty Moore Foundation

GRANTS

Armin Bahl
Emmy Noether Research Program of the DFG and 5-year Research Fellowship of the Zukunftskolleg Konstanz

Clemens Bechinger
DFG grant "Fluctuations and Nonlinearities in Classical and Quantum Matter beyond Equilibrium" for 4 years

Aneesh Bose
Independent Research Grant from Zukunftskolleg

Hanja Brandl
Independent Research Grant from Zukunftskolleg

Einat Couzin-Fuchs
DFG Individual Research Grant “Odor coding and decision making” for 3 years

Andrea Flack
Emmy Noether Research Program of the DFG

Urs Kalbitzer
Elite Programme for Postdocs of the Baden-Württemberg Stiftung

Daniel Keim
DFG Schwerpunktprogramm „RATIO“ grant „CUEPAQ Visual Analytics und Linguistik für Erfassen, Verständnis und Erklärung personalisierter Argumentqualität, for 3 years and BMBF grant for Verbundprojekt „AIDA TI UKON“ for 2 years

Katrin Vogt
Independent Research Grant from Zukunftskolleg

Anja Weidenmüller
Bees & Trees Foundation

Publications 2021

PUBLICATIONS

1 Arrondo, E., García-Alfonso, M., Blas, J., Cortes-Avizanda, A., De la Riva, M., Devault, T. L., Fiedler, W., **Flack, A.**, Jimenez, J. and Lambertucci, S. A. (2021). Use of avian GPS tracking to mitigate human fatalities from bird strikes caused by large soaring birds. Journal of Applied Ecology 58: 1411– 1420. *DOI: 10.1111/1365-2664.13893*

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25 Costa, J. S., Hahn, S., Araujo, P. M., **Dhanjal-Adams, K. L.**, Rocha, A. D. and Alves, J. A. (2021). Linking migratory performance to breeding phenology and productivity in an Afro-Palearctic long-distance migrant. Scientific reports 11(1): 23258. *DOI: 10.1038/s41598-021-01734-0*

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31 **Davidson, J. D.**, Vishwakarma, M. and **Smith, M. L.** (2021). Hierarchical Approach for Comparing Collective Behavior Across Scales: Cellular Systems to Honey Bee Colonies. Frontiers in Ecology and Evolution 9: 581222. *DOI: 10.3389/fevo.2021.581222*

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Small Projects 2021

Title	Applicants
'Frame of mind' - How neurochemical modulation mediates context-dependent decision-making in social insects?	Divya Ramesh, Christoph Kleineidam
Resubmission of S20-01: 2021 Early Career Social Learning Researchers Workshop	Michael Chimento, Julia Penndorf, Sonja Wild, Simeon Smeele, Stephen Tyndel
Social interactions of female and male Montagu's harrier in Spain	C. Giovanni Galizia, Georg Heine, Ajay Kumaraswami, Brigitte Berger-Geiger, Martin Wikelski
Neurobiology of social behaviour in insects	Divya Ramesh, Einat Couzin-Fuchs, Morgane Nouvian
Testing the ecological and evolutionary drivers of social information use in foraging bats specialized on ephemeral insect prey	Jenna Kohles, Dina Dechmann, Ari Strandburg-Peshkin, Gabriella Gall, Hanja Brandl
Leveraging long-term data to investigate ecological drivers of individual and collective behaviour in wild primate groups	Urs Kalbitzer
Coordination and cooperation across species boundaries	Alex Jordan, Myriam Knöpfl
Energetics of movement and social behaviours	James A. Klarevas-Irby
Collective motion while foraging in nutritionally-imbalanced environments	Vishwanath Varma, Felix Oberhauser, Jacob Davidson, Aya Goldshtein, Stephen Simpson, Einat Couzin-Fuchs, Iain Couzin
Investigating nut-dropping in carrion crows using state-of-the-art tracking technology	Barbara Klump
Supporting safe, inclusive and diverse field biology by amplifying underrepresented voices and providing mentoring resources for early career biologists	Eli Strauss, Tracy Montgomery, Chase Nunez
Cracking Capuchins: Stone tool use by whitefaced capuchins (Cebus capucinus imitator)	Brendan J. Barrett, Zoë Goldsborough, Evelyn del Rosario
What makes a social brain? Comparative neuroanatomy of social cichlids	Alex Jordan, Falk Schreiber, Armin Bahl
Social and vocal complexity in a communally nesting parrot	Simeon Quirinus Smeele, Lucy Aplin, Mary Brooke McElreath, Juan Carlos Senar, C. Bergler
Reshaping Nature – scientific data meets Art and Design	Hemal Naik, Falk Schreiber, Karsten Klein, Mario Doulis, Jörg Frohnmayer
Consumable	Fumihiro Kano

Medium-sized Projects 2021

Title	Applicants
Resubmission: Contagion of stress and its effect on behaviour and immune responses in groups of mice automatically tracked in a semi-natural environment	Dennis Mink, Dennis Horvath, Ahmed El Hady, Jacob Davidson, Hemal Naik, Bastian Goldlücke, Petra Wirtz, Jens Prüssner, Marcus Groettrup
Social sampling of the energy landscape: observing airflows for cost-efficient collective movement	Hannah Williams, Falk Schreiber, Britta Renner, Matthew Wilkes, Timm Richlick, Roi Harel, Kamran Safi, Martin Wikelski
Establishing fecalFACS as a method to investigate the genomic relatedness networks that underlie social interaction networks in natural animal populations	Gisela Kopp, Dina Dechmann, Urs Kalbitzer

Title	Applicants
The effect of early experience on individual vocal flexibility and group functioning	Gabriella Gall, Ariana Strandburg-Peshkin, Joah Madden, Andrew Radford
Probing collective misperceptions: Health and Economic Inequalit in Comparative Perspective	Britta Renner, Claudia Diehl, Harald Schupp, Barbara Binder
Collective tele presence through HR Cylindrical Displays	Oliver Deussen, Wolfgang Gaissmaier, Helge Giesse, Fumihiro Kano, Britta Renner, Harald Schupp
Eye-tracking and motion capture of a human group in a 3D space	Fumihiro Kano, Michael Chimento, Lucy Aplin, Harald Schupp, Britta Renner, Jana Straßheim, Mathias Günther, Oliver Deussen
Brain-wide neural activity representation of larval zebrafish social behaviour	Armin Bahl, Katja Slaangewahl, Maite Börsig, Heike Naumann, Iain Couzin
Neural circuits underlying collective behaviour in Drosophila larvae	Katrin Vogt
Worm behavioural imaging system	Serena Ding
Establishing Siberian jays as a model system to understand the fitness consequences of collective behaviours	Michael Griesser
The neural basis of gregarious behaviour in locusts – Funding for a microscope	Einat Couzin-Fuchs
Developing next-generation VR for freely moving animals	Iain Couzin, Liang Li, Armin Bahl, Daniel Calovi, Oliver Deussen
Collective motion while foraging in nutritionally-imbalanced environments	Vishwanath Varma, Felix Oberhauser, Jacob Davidson, Aya Goldshtein, Stephen Simpson, Einat Couzin-Fuchs, Iain Couzin

Title	Applicants
Computing infrastructure for the Imaging Hangar	Oliver Deussen, Felix Petersen, Hemal Naik, Bastian Goldlücke, Urs Waldmann
Social Homeostasis in Bumblebees – Extension A2	Anja Weidenmüller
Modelling collectives with multi-layer network	Tatjana Petrov, Stefano Tognazzi
Addendum to “Communication in collectives” big chunk proposal	Ariana Strandburg-Peshkin, Vlad Demartsev
Assessing the Congo Basin’s landscape of fear: Spatiotemporal dynamics of animal and human movement ecology	Barbara Fruth
Responding to physical and social cues leads soaring birds toward optimal migration routes	Elham Nourani, Sabine Storandt, Lucy Aplin
Multisampler for creating odour-mixture stimuli in physiological recordings	C. Giovanni Galizia, Morgane Nouvian, Einat Couzin-Fuchs
How collective sensing, ontogeny and individual condition influence migration in a gregarious African fruit bat	Dina Dechmann, Edward Hurme
Collective foraging in dynamic nutritional landscapes - Using high-resolution tracking data to investigate individual and group-level movement patterns	Urs Kalbitzer
Causes life-span variation in a highly social bat	Dina Dechmann, Rachel Page, Emma Teeling, Luisa Gomez
Spread of physiological states in the collective – A1 budget extension	Jens Pruessner, Petra Wirtz, Marcus Groettrup, Hanja Brandl
LED light source for calcium imaging	C. Giovanni Galizia, Morgane Nouvian
A platform to study hydrodynamic benefits in schooling fish in 3D formations	Liang Li, Daniel Calovi, Oliver Deussen

Large Projects 2021

Title	Applicants
Upgrading the Imaging Barn: Higher-resolution cameras for animal experiments	Fumihiro Kano, Mathias Günther, Michael Chimento, Bastian Goldlücke, Urs Waldmann, Hannah Williams, Timm Richlick, Britta Renner, Matthias Kraus, Johannes Fuchs, Mate Nagy
A new imaging lab for human experiments	Fumihiro Kano, Mathias Günther, Michael Chimento, Bastian Goldlücke, Urs Waldmann, Hannah Williams, Timm Richlick, Britta Renner, Matthias Kraus, Johannes Fuchs, Mate Nagy
Social transmission of predation risk across wild groups of Verreaux's sifaka	Tracy Montgomery, Zea Walton, Meg Crofoot, Ariana Strandburg-Peshkin, Wataru Toyokawa
Dual camera fluorescence microscope for worm behavioural imaging	Serena Ding
Camera array worm behavioural imaging system	Serena Ding
How do ecological and social niches coevolve?	Swastika Issar, Falk Schreiber, Alex Jordan
Foraging decision-making and navigation in bumblebees	Aya Ganoldshtein, Anja Weidenmüller
Decision-making in a group: Behaviour and neural circuits	Katrin Vogt, Einat Couzin-Fuchs
Reading neuromodulation online: fast-scan cyclic voltammetry in brains of social insects	Christoph Kleineidam, Moritz Schlötter, Armin Bahl, Divya Ramesh
Collective responses to forecasted landscape-scale resource variation	Chase Nuñez, Roi Harel, Meg Crofoot
Fictive movement recordings in juvenile zebrafish in virtual environments	Armin Bahl, Katja Slangewal, Sandrien Huber
The Collective behavior of Plants - addendum and part of Big Chunk project	Isaac Kazuo Uyehara, Alex Jordan, Oliver Deussen, Mark van Kleunen
Visual analytics for deep learning on collective behaviour networks	Daniel Keim, Michael Grossniklaus, Falk Schreiber, Sabine Storandt
Project C1: Automated tracking methods and interactive virtual environments	Oliver Deussen, Bastian Goldlücke, Michael Grossniklaus
The collective behaviour of plants	Isaac Kazuo Uyehara, Alex Jordan, Oliver Deussen, Mark van Kleunen
What makes groups successful? The interaction between individual and group-level social phenotype	Michael Griesser, Hanja Brandl, Karl Cottenie, Meg Crofoot, Carel van Schaik, Charles Efferson
Collective foraging and social search in vast decision-making spaces	Wataru Toyokawa, Hansjörg Neth, Wolfgang Gaissmaier
Examining the neuronal and physiological basis of social and collective behaviour using virtual environments	Alex Jordan, Oliver Deussen, Armin Bahl
Quantifying joint action and culture across species using cutting-edge motion capture and gaze tracking technologies	Fumihiro Kano, Michael Chimento, Lucy Aplin, Britta Renner
Individual and collective appetite for food and play – how is eating, talking and playing together shaped by social influence?	Britta Renner, Harald Schupp, Daniel Keim, Martin Wikelski, Fumihiro Kano
Modulators and consequences of stress transmission in the collective	Jens Pruessner, Petra Wirtz, Marcus Groettrup, Hanja Brandl
Communication in collectives: The dynamics of multi_x0002_participant exchange in social groups	Ariana Strandburg-Peshkin, Vlad Demartsev, Marta Manser, Dan Stowell
Decision-making in a group: behaviour and neural circuit	Katrin Vogt, Einat Couzin-Fuchs

PROJECTS 2021

PROJECTS 2021

Title	Applicants
Multi-scale analysis of locust swarms	Iain Couzin, Einat Couzin-Fuchs, Jacob Graving, Oliver Deussen, Jacob Davidson, Ahmed El Hady, Clemens Bechinger, Stephen J. Simpson, Gregory Sword
From neural dynamics to individual and collective behaviour in zebrafish	Armin Bahl, Iain Couzin, Oliver Deussen, Jacob Graving, Liang Li
Data-aware multi-layer collectives	Tatjana Petrov, Stefano Tognazzi, Julia Klein
Self-organization during honeybee colony defence	Morgane Nouvian, Giovanni Galizia

Small Projects 2020

PROJECTS 2020

Title	Applicants
2020 Early Career Social Learning Researchers Workshop	Michael Chimento, Julia Penndorf, Sonja Wild, Simeon Smeele,Stephen Tyndel
Desert locust field study	Einat Couzin-Fuchs, Felix Oberhauser, Yannick Günzel and Inga Petelski
Travel grant to the EuroVis 2020 to present the paper: “Motion Glyphs: Visual Abstraction of Spatio-Temporal Networks in Collective Animal Behaviour”	Eren Cakmak
A computational approach to information-sharing and social generalization in collective risky decision-making	Wataru Toyokawa, Wolfgang Gaissmaier, Kevin Laland, Helge Giese, Laurel Fogarty, Charley Wu
Financial support for the conference "Computational Methods in Systems Biology"	Jacob Davidson, Tatjana Petrov, Stefano Tognazzi
MoveKit – Movement Analysis Toolkit	Eren Cakmak, Daniel Keim, Jolle Jolles, Alex Jordan
Honeybee mass stinging behaviour: Data-informed parameter inference for population Markov chains	Matej Hajnal, Tatjana Petrov, Morgane Nouvian
TEDxKonstanz – outreach event	Angela Albi
Combining drone-based behavioural observation with long-term data for deeper insights into collective processes	Blair Costelloe, Ben Koger

Medium-sized Projects 2020

Title	Applicants
Deep learning of priors for bayesian inverse Problems in image Analysis	Bastian Goldluecke, Stefan Volkwein
Collective transmission of physiological states and behaviour in fish	Aneesh Bose
A software framework for multisensory environments	Hemal Naik
Active sensing and collective motion in groups	Thejasvi Beleyur

Large Projects 2020

Title	Applicants
Spatial dynamics of mate-choice in blackbuck leks	Akanksha Rathore, Vivek Hari Sridhar, Hemal Naik, Meg Crofoot, Ari Strandburg-Peshkin
Collective behaviour of active colloidal particles via reinforcement learning	Clemens Bechinger
Environmental uncertainty shapes rats' foraging behaviour in large-scale environments	Ahmed El Hady, Jacob Davidson, Tatjana Petrov

Small Projects 2019

Title	Applicants
A user-friendly tool for stress level measurement	Antonin Sulc
Co-funding for the 2019 "Digital Society" conference	Thomas Hinz
Deep reductions for modelling collectives	Denis Repin
Individual to group behaviour of mutant zebrafish	Dan Bath, Katherine Conen, Jacob Davidson
Modern machine learning methods for mapping honeybee nests	Michael L. Smith, Ben Koger

Large Projects 2019

Title	Applicants
Human-in-the-loop analysis of collective eating behaviour	Hanna Schäfer
The role of communication structure in consensus decision-making in human and animal groups	Helge Giese, Ariana Strandburg-Peshkin

Starting projects 2019

Title	Applicants
A1: Short and long-term spread and modulation of individual physiological stress states in the collective	Damien Farine, Marcus Groettrup, Jens Pruessner, Petra Wirtz
A2: The dynamics of social transmission in structured contexts	Wolfgang Gaissmaier, Christoph Kleineidam, Anja Weidenmüller
A3: Individual and collective appetite – how is eating shaped by social influence?	Britta Renner, Harald Schupp
A4: Mechanisms underlying hetereogeneity in social learning between individuals and groups	Lucy Aplin
A5: Preferences and incentives for innovation	Urs Fischbacher
B1: Using immersive virtual reality to reveal the dynamic structure of social interactions during collective decision-making	Iain Couzin, Einat Couzin-Fuchs, Oliver Deussen, Alex Jordan
B2: From the coordination of individual brains to effective collective decision-making	Wolfgang Gaissmaier, Harald Schupp
B3: Signalling and collective decision-making in moving animal-groups	Ariana Strandburg-Peshkin
B4: Collective sensing over multiple scales during migration	Einat Couzin-Fuchs, Dina Dechmann, Martin Wilkelski
B5: The global animal collective – an intelligent, networked sensing system for our planet	Dina Dechmann, Martin Wikelski
C1: Automated tracking methods and interactive virtual environments	Oliver Deussen, Bastian Goldlücke, Michael Grossniklaus
C2: Progressive visual analytics of collective behaviour data	Daniel Keim, Falk Schreiber
C3: Formal modelling of collective systems	Tatjana Petrov

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