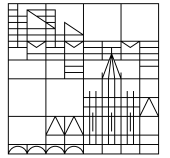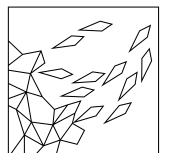Universität
Konstanz

CASCB
ANNUAL REPORT

2022

Centre for the Advanced Study
of Collective Behaviour

Dear community!

As we approach the end of 2022, it has already been four years since we started our journey with the Centre for the Advanced Study of Collective Behaviour at the University of Konstanz. We have been a fast-growing community and a community that has been growing together. The older ones among us still remember how little we knew of each other in the beginning and, if we are honest, how little we knew exactly what we were supposed to do together, with all these people from unfamiliar disciplines studying a host of unusual systems. Looking at 2022, it is amazing how different this is now. We may not yet have found a unified model for collective behaviour – and it is also good to save some goals for the second funding period – but we are increasingly finding common ground, a common language, common concepts, and unified perspectives.

A major highlight in this regard was our autumn retreat at Schloss Marbach, which gave us an atmosphere worthy of a cluster of excellence (and with quite enjoyable meals for a start). Most importantly, it brought all of us together in person for the first time after a dire period of video conferences and working from home due to COVID-19. It felt like taking a deep breath, like taking a break from all the crises that have been and still are a heavy burden for this planet and its inhabitants, without denying or downplaying their existence. We have been working on the past, present, and future of the cluster, across and within levels of experience and disciplines, with the goal of identifying unifying major research questions and mechanisms of collective behaviour, across species and systems. Researchers have inspired us with talks about robot swarms, the ecology of bonobos,

the commonalities between paragliders and Andean condors when moving through the air, as well as how birds might consider an integrated concept of beauty in mate choice.

As was also directly visible at the retreat, our community is a fascinating crowd: it currently consists of about 150 people, including principal investigators, postdoctoral researchers, doctoral candidates, affiliate members, as well as a never-tiring office team that always backs us, keeps us going, and helps us to radiate our insights to the outside world. Importantly, we have added another core competency to the cluster office with two research data managers. Given that the data we collect are growing rapidly both in terms of quantity as well as complexity, as are the reporting standards in terms of transparency and security, outstanding support is extremely useful for our community. Please make use of it!

Our community is not only growing in size but also in its research activity. In sum, there have already been more than 340 publications that have resulted from our endeavours. In 2022 as well, these were included in major outlets such as Science, Science Advances, and Nature Communications. Besides publishing their exciting work, members of our community have been extremely successful in acquiring prestigious awards and grants, such as a Gottfried Wilhelm Leibniz Prize, one ERC Consolidator Grant, one ERC Starting Grant, and a Freigeist Fellowship from the Volkswagen Foundation. Furthermore, we are pleased to announce that we can present our first "fully homegrown" doctoral researchers, who have graduated at the Centre for the Advanced Study of Collective Behaviour. Finally, the Imaging Hangar – one of the competitive advantages of our cluster – is up and running and will soon house exciting experiments with ants, locusts, other intriguing species, and robots.

With extreme sadness, we would like to acknowledge here that 2022 has also been the year in which we have mourned our esteemed colleague and friend Professor Marcus Groettrup, who passed away after a serious illness on 2 June 2022, just a few weeks after his 58th birthday. His pioneering immunological research made valuable contributions to the understanding of immune responses to therapeutic approaches to fighting disease, e.g. for developing an immunotherapy to treat cancer. In the cluster, Marcus played a leading role in the study of the transmission of stress in a range of species, one of our major research foci. He will be dearly missed by all of us, both professionally and personally, and we would like to offer our sincerest condolences to his family.

Yours cordially,

Iain Couzin

Oliver Deussen

Wolfgang Gaissmaier

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Look what we have achieved in 2022

Staff headcount

26 Academics

CASCB Projects and Group Leaders 22

25 Doctoral Candidates

17 CASCB Doctoral Network

16 Early Career Researchers

36 Affiliate Members

21 Alumni

10 Office Members

Collaboration

5 Diversity & Inclusion

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23 CASCB Seminars

Teaching — 3 University Courses

Awards

Research

103 Publications

32 Funded Projects

1 Visitor Speaker Grant

7 Travel Grants

Neurobiology Doctoral Students Workshop's Best Poster Award 1

Security Innovation Award 1

Board of Die Junge Akademie 1

Gottfried Wilhelm Leibniz Prize 1

University Council Prize 2022 1

Vice-President of the German Nutrition Society 1

Best Student Talk at the joint EFP-GfP Conference 1

Highly Cited Researcher 1

Falling Walls Global Call Winner 1

Neurobiology Doctoral Students Workshop's Best Talk Award 1

Grants

29

See all grants and awards on page 134

Imaging Hangar

The Imaging Hangar has made further progress in 2022. Even the first experiments took place! This is what has happened:

New equipment

- ➔ 40 motion capture cameras
- ➔ 12 visual monochrome cameras for markerless tracking
- ➔ Roughly 500m of cables
- ➔ Daylight system with up to 10,000 lux
- ➔ Netting

Experiments

- ➔ Robocar race, Liang Li
- ➔ Quality control of leaf fragments on foraging trails of leaf-cutting ants, Christoph Kleineidam
- ➔ 2K locust experiment, Luke Costello, Mark Bugden, and Vishwanath Varma

Guided tours

- ➔ Including: Science Night, school classes, University of Konstanz staff

Film shootings

- ➔ For example: Terra X, Arte, SWR Studio Friedrichshafen
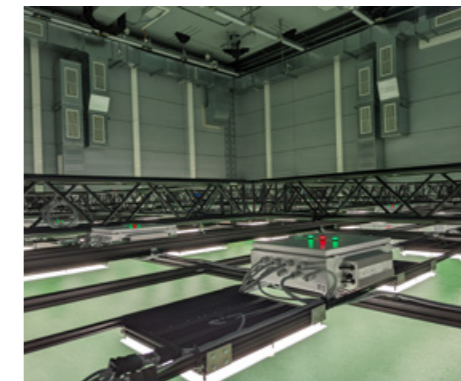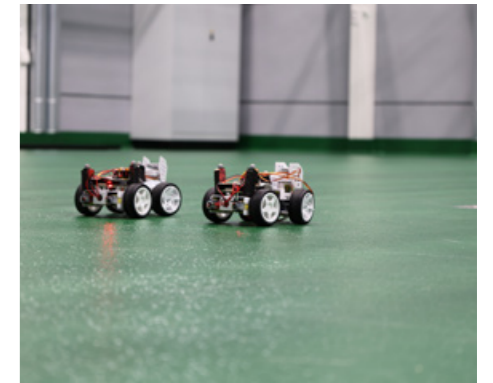
Imaging Hangar experiment: Quality control of leaf fragments on foraging trails of leaf-cutting ants

SETUP

In the Imaging Hangar, a colony of leaf-cutting ants established a semi-natural, foraging trail 30m in length. Christoph Kleineidam and Tim Temizyürek's aim was to study the optimization of trails (ant routing and obstacle removal) and the optimization of leaf intake to the nest.

Leaf-cutting ants cut and collect leaves, which they transport on physically formed foraging trails to the nest. In nature, these foraging trails are long, some-times more than 200m between the nest and the site where the leaves are cut.

FUNGUS

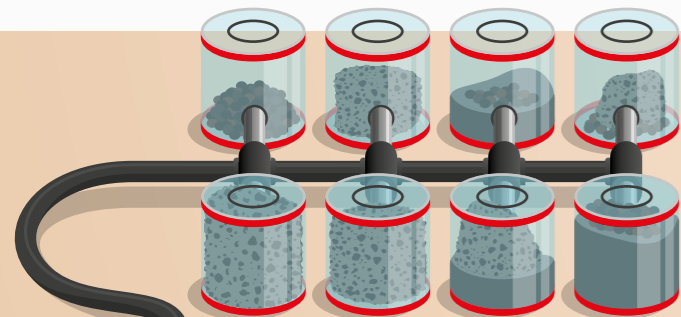Once the leaf fragments arrive at the underground nest, they are cut down further into small pieces and used as substrate for a symbiotic fungus. The fungus is the only food source for the brood, and its optimal growth is crucial for the huge ant colonies with more than one million individuals in mature nests in the wild.
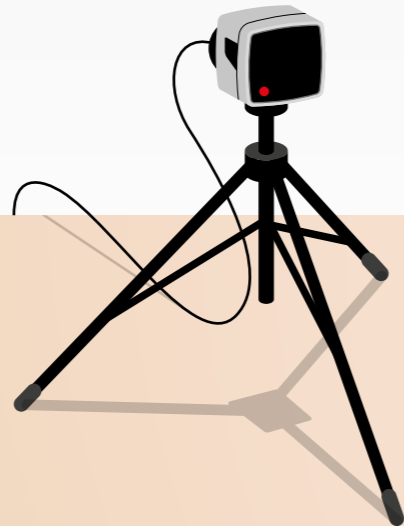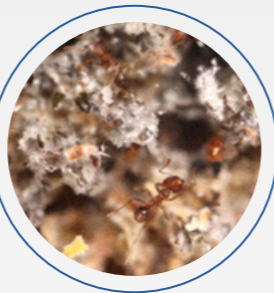
TRACKING SYSTEM

The Imaging Hangar tracking system allows us to collect detailed experimental data on leaf fragment transport. Based on these data, we can build a model that incorporates individual behaviour, including decisions to pick up and transport leaf fragments, and we can test the adaptive value of different trail length and foraging bout durations under changing environ-mental conditions, e.g. for different plant qualities.

LEAF CUTTING

The selection of suitable plant material is of para-mount importance for the colony. The first level of plant selection is done by those workers responsible for cutting fragments from the plants. Most of these fragments fall to the ground.

FORAGING BOUTS

A colony of leaf-cutting ants only forages for about three hours twice a day (two foraging bouts). This limited foraging time terminates the intake of leaf fragments, and the colony abandons those frag-ments that arrive late.

LEAF QUALITY CONTROL

Each and every leaf fragment dropped on the trail is inspected. Eventually, another worker will pick up the fragment and transport it further towards the nest. Good-quality leaf fragments are picked up quicker. This leads to a delayed arrival of low-quality frag-ments at the nest entrance.

CAFETERIA

We provide the ants with pieces of filter paper of different qualities. The quality of our artificial leaves is controlled by mixing and applying highly attractive orange juice with different concentrations of a bitter substance (tannin). A tag on these artificial leaf fragments allows us to follow them with the Imaging Hangar tracking system along the entire trail

RESULT

The process of selecting and transporting suitable plant material for the symbiotic fungus is based on individual decisions on selecting and transporting leaf fragments. The emerging pattern of leaf fragments arriving at the nest is the result of collective decision-making along the trail. It is the interaction of trail length, duration of the foraging bout, and individual decisions on the trail, made by each and every worker encountering a leaf fragment, that finally leads to the collective decision of the colony to admit only the best available plant material for the fungus.

2,000 locusts marching

" *In November 2022, Mark Bugden, Vishwanath Varma, and I ran a pilot experiment on locust swarms. Normally, locusts are studied in the lab in small groups of maybe 200 animals in small arenas, despite swarming in groups of millions of individuals in the wild. Here we were looking to explore the role that scale plays in observed behaviour of locust swarms in lab settings by increasing the size of the arena and the number of individuals. In the current experiment, we used about 2,000 locusts in an arena two metres in diameter, with the goal of scaling up to roughly 10,000 locusts in an arena five metres in diameter."*

Luke Costello
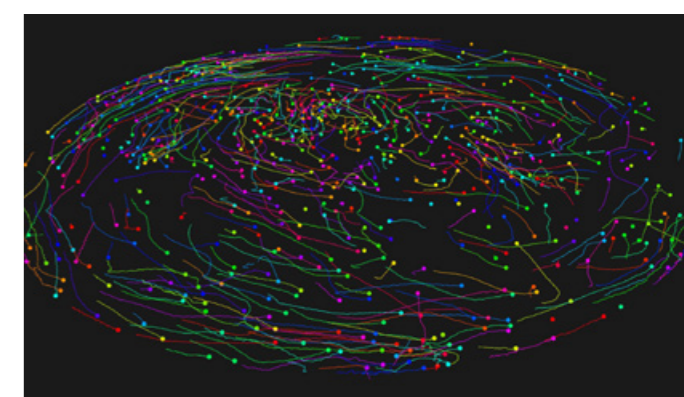
Our main publications

Hidden costs from herbicide exposure to pollinating social insects of swarm behaviour

Glyphosate, the most commonly used herbicide worldwide, affects the collective ability to maintain the necessary high brood temperatures in bumble bees. Especially during periods of resource limitation, long-term glyphosate exposure of colony members results in a decrease in the ability of the collective to maintain required hive temperatures. For pollinators in heavily stressed ecosystems, glyphosate exposure thus carries hidden costs that have so far been largely overlooked (Weidenmüller, Kleineidam et al. 2022, *Science*).

Contexts of social transmission and cultural evolution across species

In the context of cumulative cultural evolution (CCE), researchers developed the concept of efficiency by reviewing recent potential evidence for CCE in animals, clarifying a useful definition of efficiency by synthesizing perspectives found within the literature, and discussing what factors might impinge on the informational bottleneck of social transmission (Gruber, Chimento, Aplin et al. 2022, *Philosophical Transactions of the Royal Society of London, Series B*).

Wild, urban living, sulphur-crested cockatoos might be a potential case of an interspecies 'innovation arms race', where the socially learnt behaviour of opening and raiding of household bins by cockatoos is met with increasingly effective and socially learnt bin-protection measures by human residents. Such foraging innovations in wild animals can enable adaptive flexibility but also lead to human-wildlife conflicts and are yet vastly unexplored (Klump, Farine, Aplin et al. 2022, *Current Biology*).

Via evaluation of support for predictions from the social learning literature within the context of migration, findings suggest that social influences during migration are likely more widespread than previously recognized. Researchers make the case that future research on social migration can leverage next generation tracking techniques and experimental manipulations of the social environment. Movement diversity constitutes the building blocks of migration culture and thus warrants further consideration in conservation and management of migratory species (Aikens, Flack et al. 2022, *Trends in Ecology and Evolution*).

The role of social context in collective animal and human decision-making

Unique integration of exact and statistical methods provides a quantitative characterization of uncertainty in a biologically plausible model of group context and individual honeybee choice to sting or not, which sheds light on how the social context influences stinging behaviour by showing that recruitment is curbed as group size grows, thus suggesting that the presence of nestmates is integrated as a negative cue by individual bees (Petrov, Klein, Nouvian et al. 2022; *PLoS Computational Biology*).

High-resolution GPS data from meerkat groups in natural habitats allowed the quantification of individual influence over both group direction and speed, resulting in a general methodological approach which can be applied to disentangle individual influence over group direction and speed in a wide range of species with cohesive movement (Averly, Sridhar, Demartsev, Gall, Strandburg-Peshkin et al. 2022, *Scientific reports*).

Simulations show how individual rules derived from a network coordination game in human groups of varying communication structure can account for group patterns and allow rapid consensus while preventing deadlocks. More links in the communication structure accelerate reaching consensus, while conflicting opinions have a slowing effect. Global consensus is facilitated by unopinionated individuals making their choices consistent with that of a local majority and previously made choices, while opinionated individuals may yield their preferred opinion under high peer or time pressure (Gaisbauer, Strandburg-Peshkin, Giese. 2022, *Social Networks*).

Through model analyses and large-scale interactive behavioural experiments, CASCB researchers found that conformist influence can indeed promote favourable risk-taking in human decision-making, even though many individuals systematically avoid risks and potential payoffs. Although strong positive feedback by copying the majority's behaviour could result in unfavourable informational cascades, a resulting differential equation model of collective behavioural dynamics identified a key role for increasing exploration by negative feedback, which arises when a weak minority influence undermines the inherent behavioural bias. This 'collective behavioural rescue', emerging through coordination of positive and negative feedback, highlights a benefit of collective learning in a broader range of environmental conditions than previously assumed (Toyokawa and Gaissmaier 2022, *eLife*).

Efficiency and fault-tolerance in swarming behaviour of microbots

Swarms of microbots made from programmable active colloidal particles (APs) can escape from a hazardous area due to a cooperative group formation. The escape efficiency remains almost unchanged even when half the APs do not respond to the threat. Results confirm that incomplete or missing individual information in robotic swarms can be compensated by other group members but also suggest strategies to increase the responsiveness and fault-tolerance of robotic swarms when performing tasks in complex environments (Chen, Bechinger et al. 2022, *New Journal of Physics*).

Mechanisms of collective intelligence: wisdom of the crowd and implications for modern societies

Reviewing cognitive and behavioural mechanisms in animals and humans can yield collective intelligence beyond the wisdom of crowds. Researchers suggest that these mechanisms can be implemented either as 'cognitive algebra', executed mainly within the mind of an individual or by some arbitrating system, or as a dynamic behavioural aggregation through social interaction of individual group members, suggesting implications for collective decision-making in modern societies characterized by a fluid but auto-correlated flow of information (Kameda, Toyokawa et al. 2022, *Nature Reviews Psychology*).

Incidental, context-specific differences across the political spectrum likely determine the impact of polarization in democratic societies, as shown by disentangling the effects of homophily (limiting interactions to one´s own group) and partisanship (holding opposing viewpoints) in an agent-based model. Model-based and experimental findings allow the construction of a more general theoretical framework of collective wisdom in polarized groups (Bak-Coleman, Couzin et al. 2022, *Collective Intelligence*).

Functional flight strategies in long-range seasonal migrating insects revealed by novel tracking methods

Using a novel method of light aircraft and individual radio tracking, researchers show that nocturnally migrating death's-head hawkmoths maintain control of their flight trajectories over long distances by not just flying with favourable tailwinds but also adjusting for head and crosswinds to precisely hold course. This behaviour indicates that the moths use a sophisticated internal compass to maintain seasonally beneficial migratory trajectories independent of wind conditions, illuminating the priorly elusive question how insects traverse long distances to take advantage of seasonal resources (Menz, Williams, Wikelski et al. 2022, *Science*).

Novel approaches to modelling and visualization of collective movement and behaviour

Incorporating machine learning into ecological workflows could improve inputs for ecological models and lead to integrated hybrid modelling tools, as outlined in a novel approach that will require close interdisciplinary collaboration to ensure the quality of novel approaches and train a new generation of data scientists in ecology and conservation (Tuia, Costelloe, Croofot, Couzin, Wikelski et al. 2022, *Nat Commun*)

4D (including 3D space + time) shape data from animals like schooling fish contain a rich array of social and non-social information that can be used to shed light on the fundamental mechanisms underlying collective behaviour and can be automatedly captured with affordable small training datasets and textureless 2D videos. Researchers generated accurate 4D shapes of schooling fish from a 3D template mesh model, showing that the method is effective for 4D shape reconstructions of swimming fish with greater fidelity than other state-of-the-art algorithms (Wu, Deussen, Li. 2022, *IEEE/RSJ International Conference on Intelligent Robots and Systems*).

The analysis of movement trajectories plays a role in collective behaviour research, where large and complex trajectory datasets are routinely collected these days. While automated analysis methods are available, human inspection is still required to interpret the results and the impact factors that influence trajectory shapes and their underlying movement processes. Researchers provide an overview of the challenges arising in robust trajectory visualization tasks and discuss several methods that contribute to improved visualizations, such as practical algorithms for simplifying trajectory sets and a complementary approach that makes it possible to visualize the uncertainty along with the trajectories (Zhang, Deussen, Storandt et al. 2022, *Information Technology*).

Our complete list of publications can be found on our website:

https://www.exc.uni-konstanz.de/ collective-behaviour/research/publications
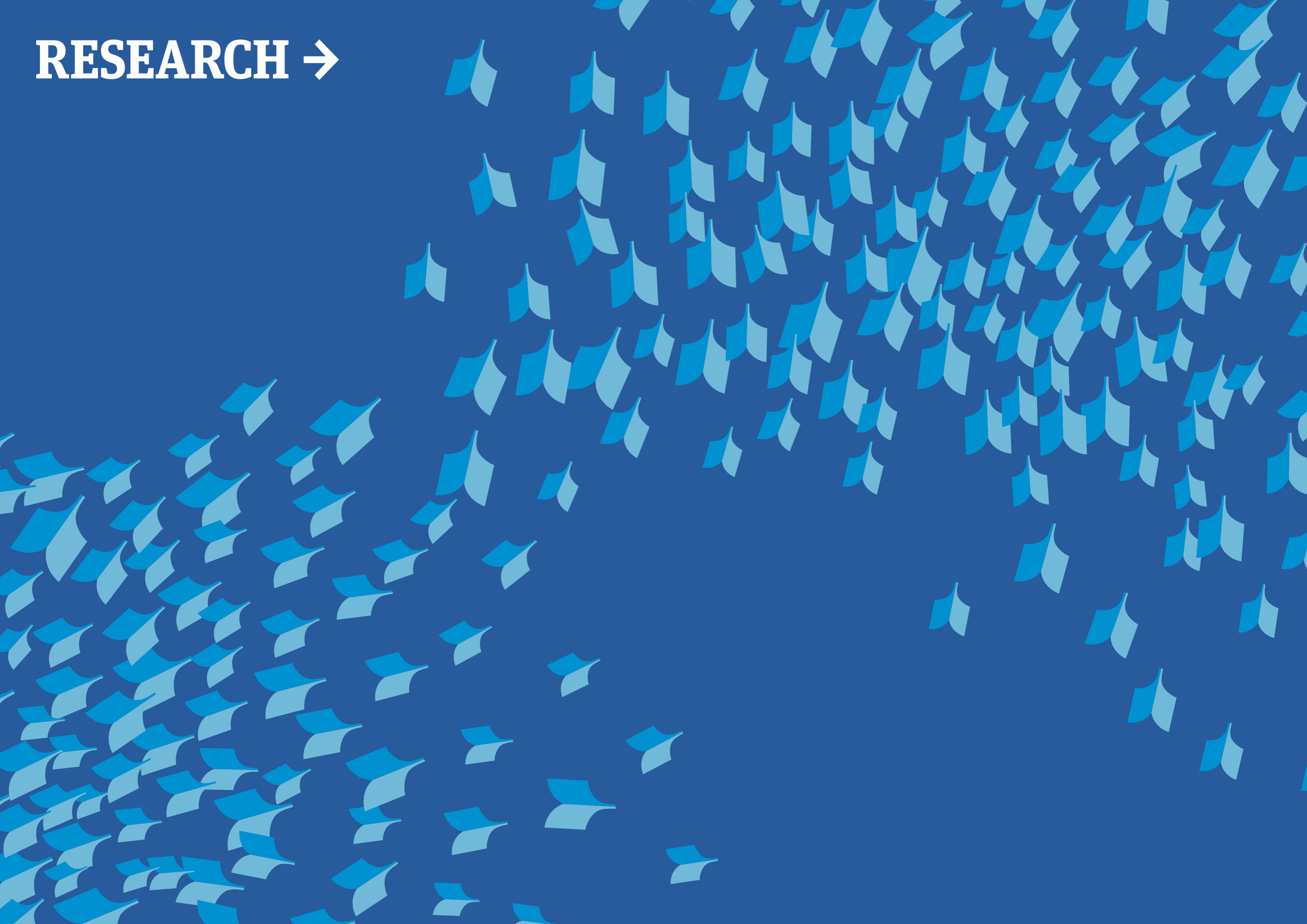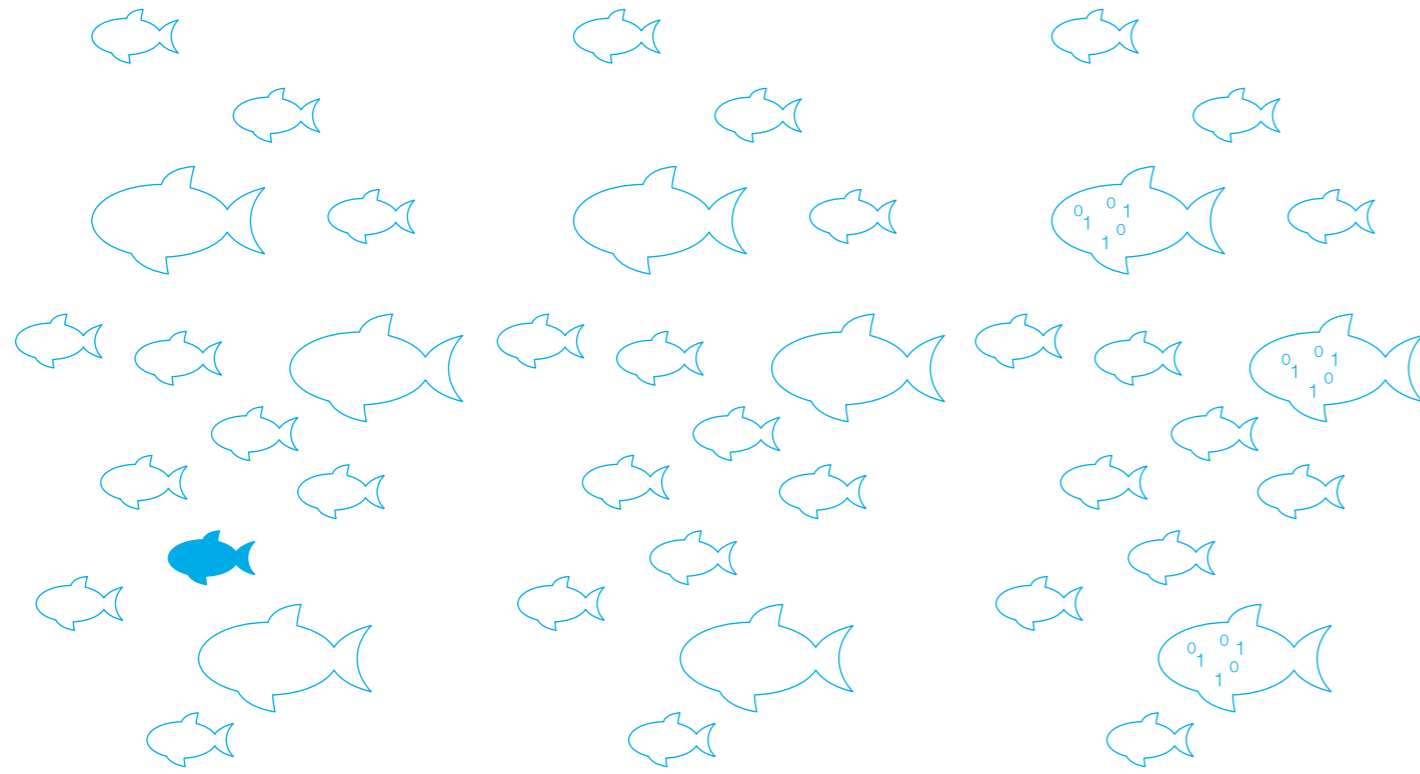
RESEARCH →

A

Individuals in the collective

B

Aggregation in the collective

C

Computational methods

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 mathematics 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, 133 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.

Individuals in the collective

Quantifying joint action and culture across species using cutting-edge motion capture and gaze-tracking technologies

What are the dynamics of social interaction in humans and animals? The project *Quantifying joint action and culture across species using cutting-edge motion capture and gaze-tracking technologies* aims to understand these specific dynamics. The research team led by Fumihiro Kano is therefore using cutting-edge tracking technologies, including motion capture, gaze-tracking, and computer vision techniques.

The team works with multiple species, including birds (pigeons and crows), primates (great apes and monkeys), and human adults. They target various types of collective behaviour, including team cooperation in humans, vigilance in pigeons, and collective foraging in all animals.

"More specifically, our goal is firstly to establish techniques to track postures and eye/head directions across species. And secondly, we want to identify key interactive components among individuals, as well as key cognitive and emotional traits of individuals, that lead to successful synchronization and joint action of a collective," Fumihiro Kano explains.

"In monkeys, using drone images and computer vision, we reconstruct the visual fields of freely foraging and freely interacting monkeys to understand how social dominance is related to the network of attention. Our dataset of a Japanese monkey troop is the most exciting for me. Our dataset is composed of individuals' positions, postures, social ranks, and kinship. We have never seen such an informative dataset in primates."

Sota Inoue (Nagoya University) and Varun Kumar (Master's student)
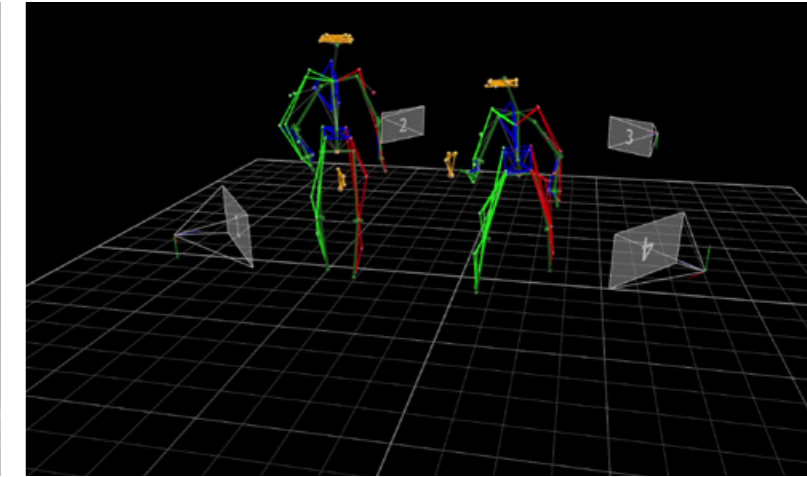
"Using a motion capture system, wearable eye-tracker, and ECG sensors, we reverse engineer the process of interpersonal joint action in humans to investigate the key components during cooperation and competition, for example while playing table tennis. I find it exciting to study human behaviour with our unconventional method. We try to study interpersonal joint action in a real environment without manual coding. This quantitative measurement will help us to understand in finer space what happens when people fail or manage to cooperate."

Prasetia Putra
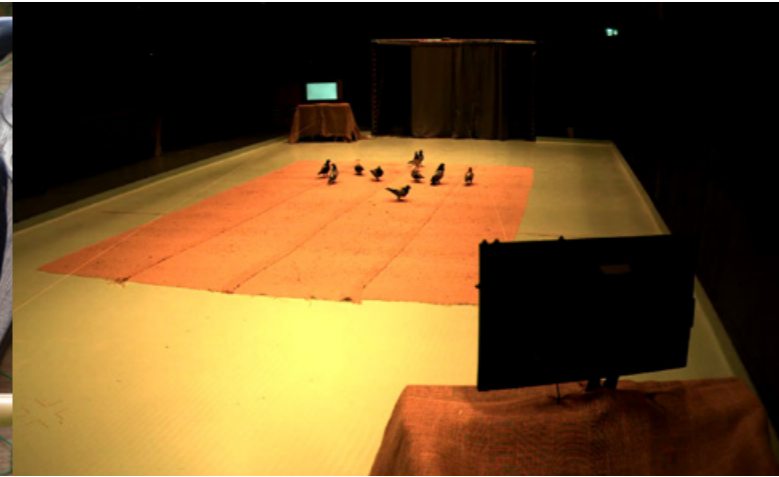
" *Using computer vision techniques, we aim to reconstruct 3D poses of multiple freely interacting birds across various species in both captivity and nature. What excites me the most is the idea that doing 3D posture tracking on multiple individuals has never been done before and developing such a method can open up limitless opportunities for new studies and research questions. Being in the very forefront of what current technologies can do is also exciting because we do not know how these methods might change the field of animal behaviour as these methods become more powerful and accessible."*

Alex Chan

" *Using a motion-capture system to study crows helps us to reconstruct the visual fields of freely interacting crows. We can better understand how crows make eye contact with/avoid conspecifics and follow the gaze of conspecifics."*

Akihiro Itahara (Kyoto University)

" *In pigeons, using a motion capture system, we reconstruct the visual fields of freely foraging and freely interacting pigeons to understand how cognition and individuality are related to the collective solving of natural tasks, such as foraging, vigilance, and navigation. Investigating the role of inter-individual differences in collective behaviour would hardly be possible without the technologies offered by the cluster. Working with technologies such as the Imaging Barn is a great challenge and very exciting!"*

Mathilde Delacoux

" *This project offered me a great opportunity to expand my study approach and range of species."*

Fuhimiro Kano

"We support the study of social interaction using various tracking technologies, including the cluster's flagship imaging facilities, the Imaging Barn, and soon the Imaging Hangar," says Fuhimiro Kano. The team aims to bridge the study of cognition and the study of collective behaviour using methodologies derived from both fields, and also from computer science. Overall, they want to develop a set of tracking technologies and datasets that can be used for these fields. Furthermore, a series of these studies should first lead to the establishment of posture-tracking methods across species and across contexts, that is, both lab and field conditions. Second, they want to obtain a quantitative understanding of the dynamics of social interaction in naturalistic real-life social interaction across species.

REVERSE ENGINEERING HUMAN JOINT ACTION IN SPORT

SETUP

We want to unravel the underlying mechanism of human coordination in sports using behavioural and physiological modalities. Our current system uses 14 motion capture cameras to track the movement of individuals, their rackets, and the ball. During the experiment, participants wear eye-tracking glasses and ECG sensors that measure their gaze direction, and heartbeat.

SESSION 1

Participant A + Participant B = **Smooth Coordination**

SESSION 2

Participant A + Participant C = **Clumsier Coordination**
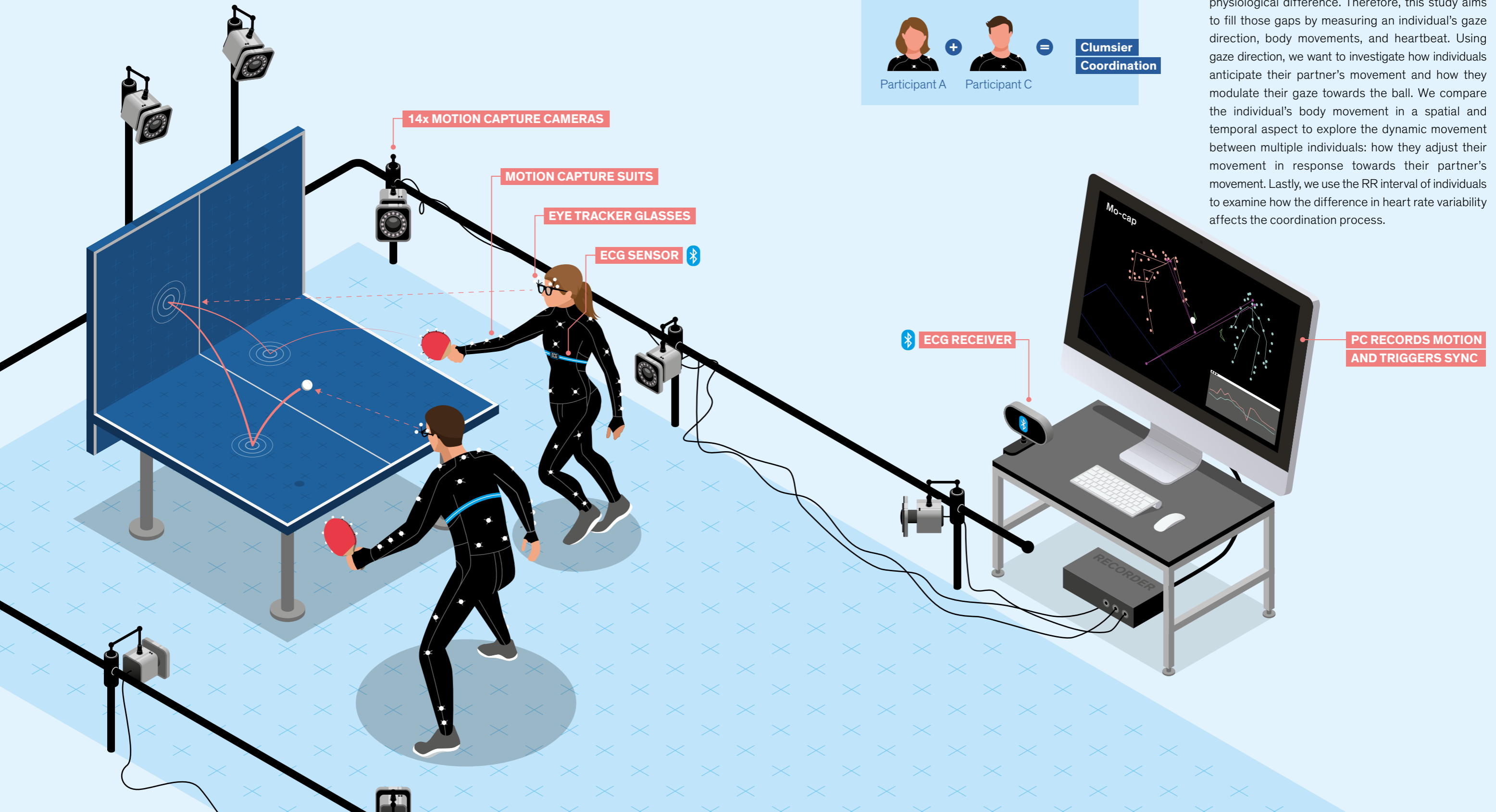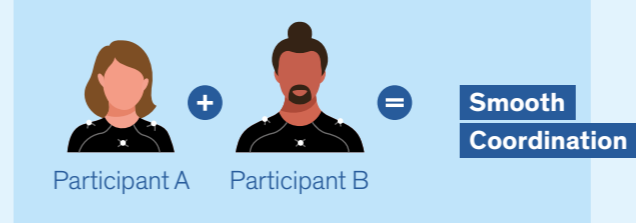
AIM OF THIS STUDY

Many studies try to answer key questions in coordination by comparing the performance of paired individuals while they are taking part in a cooperative task. When using the described method, we can understand the skill-gap and familiarity factors that contribute to the success and failure of coordination. However, what we cannot understand is the individuals' anticipation ability, movement coordination, and physiological difference. Therefore, this study aims to fill those gaps by measuring an individual's gaze direction, body movements, and heartbeat. Using gaze direction, we want to investigate how individuals anticipate their partner's movement and how they modulate their gaze towards the ball. We compare the individual's body movement in a spatial and temporal aspect to explore the dynamic movement between multiple individuals: how they adjust their movement in response towards their partner's movement. Lastly, we use the RR interval of individuals to examine how the difference in heart rate variability affects the coordination process.

14x MOTION CAPTURE CAMERAS

MOTION CAPTURE SUITS

EYE TRACKER GLASSES

ECG SENSOR

ECG RECEIVER

PC RECORDS MOTION AND TRIGGERS SYNC

Mo-cap

RECORDER

The collective behaviour of plants

How do plants move, grow, and allocate resources differently when they grow in groups versus when they grow alone? Kaz Uyehara and his project team are investigating this question in their research project *The collective behaviour of plants*. In doing so, the team is expanding collective behaviour research into the field of plant ecology.

Plants, like animals, respond dynamically to their environment and specifically react to the presence of competitors. The main way that plants can alter their behaviour is by growing and changing their orientation. Here, the research team can carefully quantify plant behaviour by quantifying the 3D structure of a plant over time.

"We seek to understand the interface between plant ecology and collective behaviour on three major scales," says Kaz Uyehara: "First, we want to investigate the physiological mechanisms that allow plant behaviour to emerge from a non-hierarchical and modular organism. Second, how do plants alter their growth and allocation in response to 'social' cues from neighbours? And third, what are the fitness consequences of specific plant behaviours?"

To answer these questions, the research team has run four studies in parallel. It took advantage of the opportunities offered by the Botanical Garden of the University of Konstanz. Furthermore, the project is multifaceted because the team combines computer vision, mathematical modelling, computer simulations, and empirical research to uncover the proximate and ultimate mechanisms that control collective plant behaviour.

"We are excited about the natural synergy between collective behaviour and plant ecology," says Kaz Uyehara. "We are on the brink of exciting models of individuals and collectives that have major repercussions at the ecosystem scale." The project is also an enrichment for the CASCB: "By drawing parallels across animal behaviour and plant behaviour, both disciplines can advance the study of collective behaviour."

Understanding and facilitating positive group dynamics in education

The project *Understanding and facilitating positive group dynamics in education* aims to increase our understanding of processes in underlying group dynamics in educational contexts, which will provide novel insights into the conditions under which positive peer group dynamics emerge and how they can be facilitated.

For this purpose, we integrate theories and methods from developmental and educational science, neuroscience, animal science, social network science, and computational science. We investigate whether children synchronize their behaviour during group activities and whether group synchronization predicts children's subjective experiences and identification during social interactions. In addition, we focus on synchronization in children's heart rate variability as a marker for shared emotional processes at the group level.

We will examine specific associations of these synchronization processes with changes in children's social representation of their peer relationships, such as their friendships and peer group membership.

Jeanine Grütter

In vitro Dopamine concentration at the electrode

Fictive movement recordings in juvenile zebrafish in virtual environments

Measuring behaviour during microscopy is critical for probing how nervous systems transform sensory information into decisions. However, imaging experiments require animals to be firmly held in place, which makes simultaneous behavioural measurements challenging. In larval zebrafish, there are two methods to overcome this problem: precise tracking of the freely moving tail in a head-restrained preparation and electrophysiological recordings from the ventral root canal in paralyzed animals.

For the project *Fictive movement recordings in juvenile zebrafish in virtual environments*, Armin Bahl and Panagiotis Eleftheriadis have built a new cutting-edge fluorescent microscope with electrophysiology capabilities. This allows them to perform such recordings. Armin Bahl and his colleagues use an online feedback approach to link motor signals to the immersive virtual environments, giving animals agency about the stimulus. So far, they have found that animals robustly follow directional motion cues.

"This new preparation allows us to systematically probe the cognitive abilities of zebrafish in a variety of different behavioural tasks, including social virtual interactions and collective decision-making," summarizes Armin Bahl.

Research Scientist Panagiotis Eleftheriadis about his project experience:

"

Incoming information through sensory systems is our only access point to our environment. The properties of neural network computing transformations of such inputs to motor outputs and observable motion, are the fundamental basis of any behaviour. Investigating the mechanics of such processes is not only a thrilling task for me as a young neuroscientist but also of major biological and even philosophical importance.

While preparing my PhD, I was lucky to come upon Armin Bahl's lab in Konstanz. I was even luckier when I got accepted for a half-year project as a visiting scientist in this amazing research group, working on establishing fictive locomotion experiments in larval zebrafish.

Getting to work, literally and figuratively, next to Armin Bahl, was one of the most educational and inspiring experiences of my career. As for the people, I can only say I will be back to see everyone very soon!"

Panagiotis Eleftheriadis

Reading neuromodulation online: fast-scan cyclic voltammetry in brains of social insects

The vast repertoire of collective behaviours seen in social insects lacks the quantification of the underlying neuromodulation that leads to interindividual variability. The project *Reading neuromodulation online: fast-scan cyclic voltammetry in brains of social insects* therefore aims to collect information about the internal state of an animal in real-time during the performance of the behaviour.

Neuromodulators can alter and adjust information processing in the brain. This can massively change neural circuit dynamics and sensory processing. How and where such modulators act in the brain remains largely unknown in any species. "We are particularly interested in how social information is processed for decision-making," says project leader Christoph Kleineidam. For measuring neuromodulation in real-time in the brains of vertebrates and insects, the team, including the physicist Moritz Schlötter, is developing a fast-scan cyclic voltammetry (FSCV) method.

So far, the team has studied context-dependent neuromodulation for individual decisions in insects, resulting in a division of labour and social organization. "We have established our FSCV measuring system for liquid samples and the resolution to quantify and to calibrate the electrode is already very good," says neurobiologist Christoph Kleineidam. "Observing real-time changes of neuromodulation in a behaviourally responding insect and being able to connect it to collective behaviour while also partly solving the 'hen-egg' paradox of post-mortem analyses is highly exciting," emphasizes Divya Ramesh, the team's mass spectrometry specialist.

Kleineidam is convinced that FSCV is "a very powerful tool" for studying the dynamics of neuromodulation. "We can now tackle the challenge of taking measurements in tiny brains of behaving insects, for example, ants, running on the treadmill." Furthermore, the plan is to extend their FSCV research and to study the rewarding nature of social signals and other reinforcers, such as the underlying mechanisms of neural plasticity in juvenile zebrafish, together with Armin Bahl.

Optimizing device and sensor programmes for monitoring collective behaviour in wild lions

None other than the king of the animals is the model system for the project *Optimizing device and sensor programmes for monitoring collective behaviour in wild lions*. The researchers Natalia Borrego and Genevieve Finerty aim to study the social grouping and collective behaviour of the lion in South Africa.

Historically, studying lion behaviour in such detail was impossible due to technological and logistical constraints. For example, lion hunts often occur at night and in dense bushland, making detailed observation impossible. In addition, lions spread out over large areas. It is therefore logistically impossible to track their movements across a landscape or collect the type of data needed to understand how they communicate and come together when distributed across a vast landscape.

→ THE LOGGERS ARE AN EXCITING LEAP FORWARD

This project tested multi-sensor devices that have the potential to overcome these challenges. "The loggers we tested in this project are an exciting step forward in the types of data we can collect and the big picture questions we can answer about our study system," say Natalia Borrego and Genevieve Finerty.

The researchers explain: "As part of our work, we will deploy collars that combine high-resolution GPS, accelerometry, magnetometry, and audio on entire groups of lions." Right now, they are analyzing the data. They are sure that the data they collected in July 2022 will generate unprecedented insights into collective behaviour at multiple spatial and temporal scales from the fine-scale group hunting behaviour to the broader scale of how lions navigate changing seasons as a group.

Cooperation in collective action: on the "hunt" for role specialization

Genevieve Finerty   **Natalia Borrego**

In recent years, there have been groundbreaking advances in the kinds of information we can collect on moving animals: GPS collars are returning positional data with increasing temporal resolution and accuracy. Our project leverages these advances to collect fine-scale data on African lion *(Panthera leo)* collective movement and behaviour.

Our overarching aim is to develop a comprehensive understanding of cooperative hunting, which raises fundamental questions about the ways in which animals perceive and communicate information, the extent to which they actively coordinate with each other to achieve joint aims, and the emergence of role specialization in animal collectives. With advances in the field of remote tracking technology, we can collect simultaneous data on the behavioural interactions of the entire pride and monitor both short- and long-distance communication among pride mates and individual-level information on foraging efficiency.

By bringing new, remote tracking tools to bear on these long-standing questions, we will develop a quantitative understanding of group hunting and role specialization across a range of spatio-temporal scales: from the second-to-second decisions from which coordinated hunting behaviour emerges to the landscape-scale patterns of splitting and merging that determine subgroup composition and the availability of cooperation partners.

Simultaneously tracking the movement, behaviour, and communication of entire lion prides across a range of ecological contexts and tying these data to the outcome of group hunts will generate unprecedented insights into the proximate drivers of variation in the dynamics of cooperative hunting behaviour. The overarching question we aim to address with this project is: When do we expect animal groups to move beyond simply hunting collectively to hunting collaboratively, and under what circumstances do we expect the emergence of role specialization? We approach this by first updating classic theoretical modelling paradigms of cooperative hunting and then using empirical data from wild lions in multiple prides to map group hunting behaviour in detail across habitat types and heterogeneous groups.

Newcomer Project

Ecological and social triggers of human (predator) and animal (prey) movement patterns in Central Democratic Republic of Congo

Barbara Fruth

While apex carnivores are known to influence the distribution and abundance of African mammal communities, the effect of human *(Homo sapiens)* predation on intra- and inter-specific collective behaviour of these communities is virtually unknown.

From January to December 2023, we will study hunters and their prey *(Cephalophus spp.)* in the rainforest of Central DR Congo. In an interdisciplinary approach, we investigate how hunters decide, coordinate, and act in a spatially explicit manner when setting out on their traditional subsistence hunting. We assess

ecological triggers, map predator and prey movements using bio-logging technology, and reveal the ethnographic, social, and economic components of traditional hunting using semi-structured interviews and economic games. We wish to understand predator-prey relations as well as individual motivations of collective hunting and cooperation and to enhance community participatory wildlife management in the buffer zone of Salonga National Park.

Newcomer Project

Tracking wild orangutans: understanding the when, where, and how of fission-fusion sociality in a great ape species

Caroline Schupli

Understanding the mechanisms that regulate association patterns among fission-fusion species is key to unravelling the principles of collective behaviour across taxa. Among orangutans — who exhibit individual-based fission-fusion sociality — very little is known about the coordination of inter-individual spacing, largely because remote tracking of wild orangutans is not yet possible. This long-term project has two major goals: 1) To develop a novel, non-invasive, GPS-based remote tracking device for wild orangutans, and 2) To deploy this device to collect high-resolution ranging data on wild Sumatran orangutans *(Pongo abelii)*. These unique data will shed light on the mechanisms underlying orangutans' inter-individual spacing patterns and significantly advance the study of collective movement and coordination dynamics in fission-fusion species. Our novel tracking device will also expand the opportunities for non-invasive tagging and movement analysis across taxa.

Following an indecisive leader – developing a virtual reality system to investigate how animals resolve incomplete social compass cues

Incomplete information, with strong components of uncertainty and ambiguity, is common in nature. While psychophysical studies have established how this affects perception by individual animals, relatively little is known for social groups in which perceived information is then transferred between individuals. We will investigate this process of transformation between physical information, biological information, and social information, and how information can be recovered at each stage. We will use polarization compass behaviour in insects as our model system for the resolution of incomplete information in social groups. Building on established methods for manipulating the ambiguity and uncertainty in polarized stimuli, we will first determine the rules underlying the active and passive propagation of incomplete information through social groups and then leverage this knowledge to develop a virtual reality system, allowing these principles to be investigated in other species.
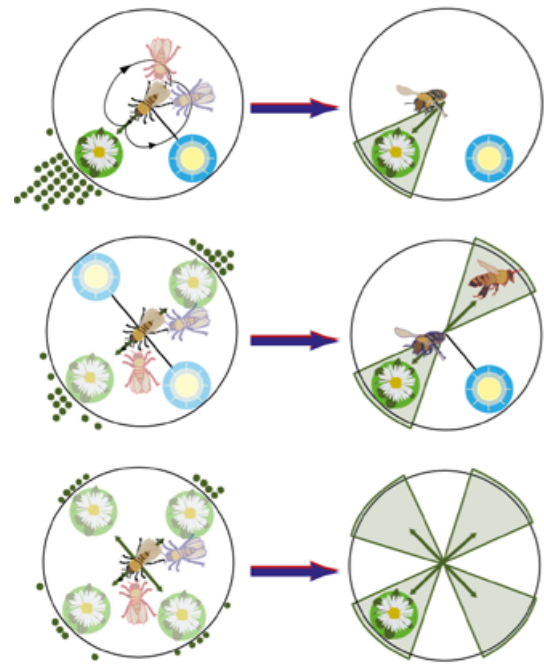
James Foster

ISMiR: the influence of interoceptive signalling on self-other perception, sensorimotor and physiological synchrony, and behaviour in social interactions within mixed reality spaces

Bigna Lenggenhager

Tiare Feuchtner

Accurate prediction, detection, and interpretation of interoceptive cues is fundamental for human cognition and interaction. This interdisciplinary project aims at developing human-computer interfaces that digitally present interoceptive signals and testing their effects in collaborative settings across mixed reality environments – either to compensate for reduced bodily signals in computer mediated settings or to enhance hidden signals in natural settings. We hypothesize that such augmentations will improve interoceptive inferences, enabling a more accurate identification of mental states, and foster synchronization and social interaction. To transfer this to a more applied context, we will adjust the developed interfaces to entrain interpersonal interoceptive synchronization and enhance inter-species empathic and pro-environmental sentiments. The results will contribute to understanding the role of interoception in cooperation and inform the design of future interactive technologies.

Area B

Aggregation in the collective

Decision-making in a group: behaviour and neural circuits

Do individuals behave differently within a group than when alone? To answer the question, the project *Decision-making in a group: behaviour and neural circuits* tracks the movement and behavioural responses of individual fly larvae and locusts in a group and alone.

Social interactions are fundamental to all life and constitute a significant part of an individual's experience. Group-living animals may potentially benefit from pooling social information for faster and more accurate assessments of their environment. Even in organisms that have traditionally been considered non-social, social influence can assist in information acquisition by increasing sensory ranges and reducing uncertainty.

Group behaviour, however, is not always advantageous due to increased competition for mating partners and food, and, in some cases, even cannibalism. Animals therefore face a complex decision-making task when modulating social tendencies.

How the neural system processes and integrates external, internal, and social information to inform this decision is not very well understood. "We propose to investigate the neural processes underlying decisions in social contexts, focusing on the sensory mechanisms used to acquire social information and how this information, which is often noisy, probabilistic, and complex, is processed to inform decision-making," Katrin Vogt explains. Einat Couzin-Fuchs adds: "Insect species, such as the fruit fly or locusts, exhibit different levels of sociality while maintaining a conserved and accessible neural architecture, thus they serve as great model systems to study the neural basis of social behaviour."

The project team performs behavioural experiments and tracks the movement of the animals with state-of-the-art tracking methods such as Trex, which was developed by the Couzin lab. Katrin Vogt and Einat Couzin-Fuchs aim to compare the behaviour and the neural processing circuits underlying social and non-social stimuli decisions between two different insect species. This comparative approach will enable them to unravel general behavioural principles governing decision-making.

" We all experienced post-pandemic changes in our attitude and sensitivity when visiting a crowded place for the first time after a while. It is captivating that similar changes in preference and sensitivity are observed across the animal kingdom, giving us opportunities to investigate the general principles mediating behaviour flexibility. I am particularly excited by the current and imminent advancement of our cluster in VR technologies and neural monitoring that are paving the way for directly tracing the specific pathways mediating these changes."

Einat Couzin-Fuchs

> " *It still puzzles me that a small sedentary and seclusive animal such as the desert locust can turn into a migrating, ravenous pest species, threatening the food supply of millions of people. The intimidating swarm formation of desert locusts only happens under favourable environmental circumstances, and I was lucky enough to be part of the research group which could witness such an event in Kenya. Seeing the vast scale and economic impact of desert locusts was upsetting and fuelled my motivation to contribute to a better understanding of the profound phase change as well as the underlying neuronal circuits.*"

Inga Petelski

> " I am interested in understanding how animals behave together in a group and if and how their behaviour changes when they are alone. Tracking the movement of fruit fly larvae in different environments and group sizes, I find that larvae in bigger groups respond less to changes in context compared to single larvae.

Akhila Mudunuri

> " It is fascinating how flexible we are in our behavioural responses towards other individuals and/or towards changing environments. I am excited every day about solving the puzzle of how the brain integrates this information and enables this flexibility. In the context of the cluster, I want to elucidate how an animal knows it is part of a group and/or in a specific context and how it then decides which behaviour to perform.

Katrin Vogt

Collective responses to forecasted landscape-scale resource variation

How might animal collectives change their behaviours to take into account variable resource landscapes changing with the climate? What will that mean for their sociality, ecological function, and conflict with humans? The CASCB project *Collective responses to forecasted landscape-scale resource variation* aims to answer these questions.

"We aim to produce forecasts of species-specific resource estimates at the scale, level of aggregation, and ecological context of the data through the integration of new and existing plant community data, satellite remote sensing, and climate projections," says Chase Núñez. From his perspective, the project's innovations have occurred naturally from an interdisciplinary approach, situating collective behaviour as a response to forecasted changes in the abundance and distribution of plant species, enabling testable predictions of how animal collectives can shape, or be shaped by, environmental change.

"This project provides a theoretical and methodological direction for collective behaviour studies to expand on the spatio-temporal scale by uniting aspects of complex systems science, community ecology, and statistical inference," he says. "The data produced by this project will not only increase the scientific value of past and future movement data but also provide a new workflow and source of data for other projects, fuelling future collaborations that we hope will extend beyond the proposed work."

Self-organization during honeybee colony defence

Honeybees defend their colony collectively against large predators by mass stinging. This behaviour requires decentralized coordination between at least two populations of bees: one responsible for the detection of threats and the other for stinging the intruder. Honeybees use the sting alarm pheromone, an odour blend carried directly on their stinger, to communicate during defensive events.

"Recently, we found that responses to the alarm pheromone changed drastically across individual bees depending on their life stage," says Morgane Nouvian. The aims of this project with the title *Self-organization during honeybee colony defence* are to understand how alarm pheromone responsiveness is regulated during the life of each bee to create this variability and how this variability, in turn, shapes the resulting collective defensive behaviour.

More specifically, the project will first investigate the link between alarm pheromone responsiveness and the age-dependent division of labour characteristics of honeybee colonies. Second, it will look for the physiological underpinnings of this variability in responsiveness. Finally, it will study the impact of this regulation on colony efficiency both during and outside of defensive events, taking into account the suicidal nature of stinging behaviour.

Overall, this project will thus build a comprehensive view of a self-organizing system, the defensive response system of honeybees.

(fUSi)

**High spatial and
temporal resolution**

Measuring brain-wide
networks with functional
ultrasound imaging

Navigation strategies

Posture

**High-resolution
video tracking**

**PATCH
FORAGING
BEHAVIOUR**

patch environment

↓   *move*

patch food density

↓   *forage*

food encounters

↓   *update*

observer belief

**Quantitative
behavioural modelling**

Environmental uncertainty shapes rat foraging behaviour in large-scale environments

In nature, rats have to survive in uncertain and harsh environments. They should therefore employ decision strategies that maximize their survival in those environments. The project *Environmental uncertainty shapes rat foraging behaviour in large-scale environments* aims to understand how uncertainty shapes the foraging strategies of rats.

To achieve this, the project team pursues two different approaches: theoretical and experimental. "On the theoretical side, we are developing models to infer the decision strategies that animals employ in different environments, using approaches from stochastic processes and decision-making models used in systems neuroscience," explains Ahmed El Hady and continues: "These models are meant to be applied to a variety of animal species and not only used for rats." On the experimental side, the team is developing a foraging behavioural paradigm in the Imaging Hangar to approximate rats' natural foraging in the laboratory.

"By combining these theoretical and experimental approaches, we can lay the foundation for understanding how rats forage in a large naturalistic environment," says Ahmed El Hady. To date, the team has been able to finalize the theoretical models and apply them to foraging data. In the next steps of the project, they will be able to use these models to design foraging experiments in the Imaging Hangar. Using the Imaging Hangar is what excites Ahmed El Hady the most: "Using this facility allows me to do experiments that cannot be done elsewhere than Konstanz." He is certain that the large-scale foraging experiments in the Imaging Hangar will allow researchers to investigate brain-wide dynamics underlying natural behaviour, for example, using the recently developed functional ultrasound imaging.
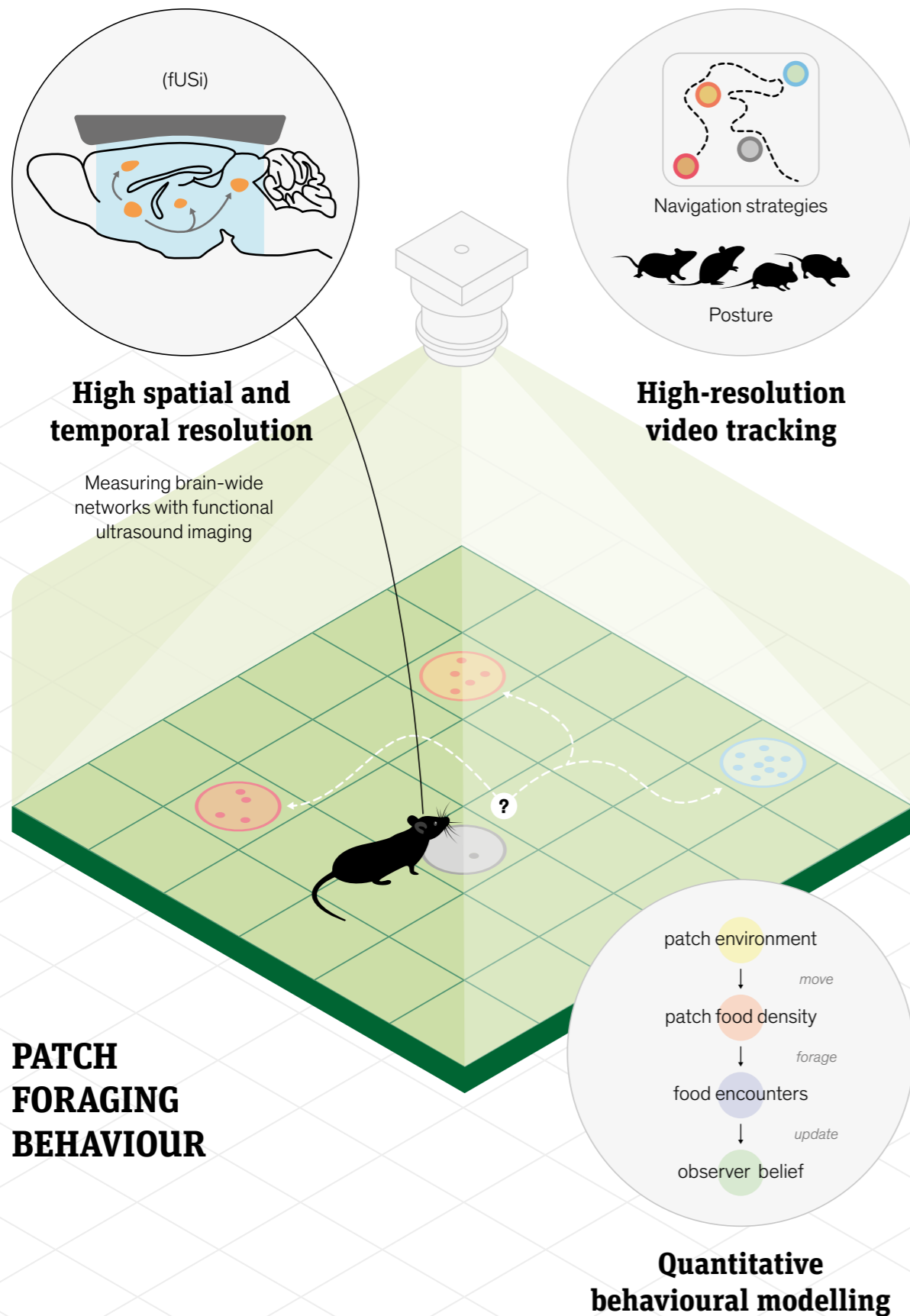
# Collective foraging and social search in vast decision-making spaces

The aim of the project *Collective foraging and social search in vast decision-making spaces* is to understand the algorithmic bases and adaptive advantages of collective search behaviour in structured, risky environments. The project will incorporate formal mathematical models and agent-based simulations into developing an understanding of the relationship between learning and decision-making processes and concomitant collective behaviour. Additionally, the project will test theoretical predictions through large-scale online behavioural experiments while comparing human data with other animals. With Jingyu Xi, a doctoral candidate who recently joined the project, the team has started searching for conditions under which social networks and hierarchical structures affect the "collective behavioural rescue" effect. "We have obtained a promising preliminary result in the social generalization experiment," says Wataru Toyokawa. "Although the project is still in its earliest stage, some of the preliminary results are promising and have already been presented at international conferences and meetings."

Individual heterogeneity to collective behaviour in nematodes

Serena Ding
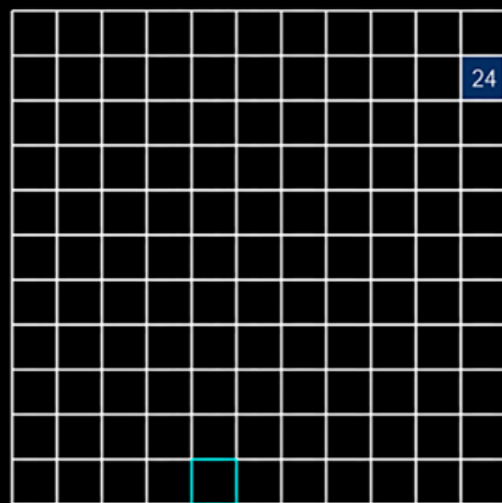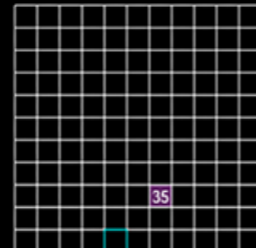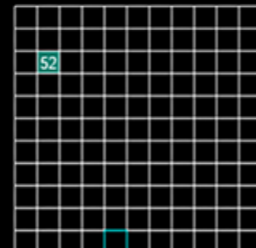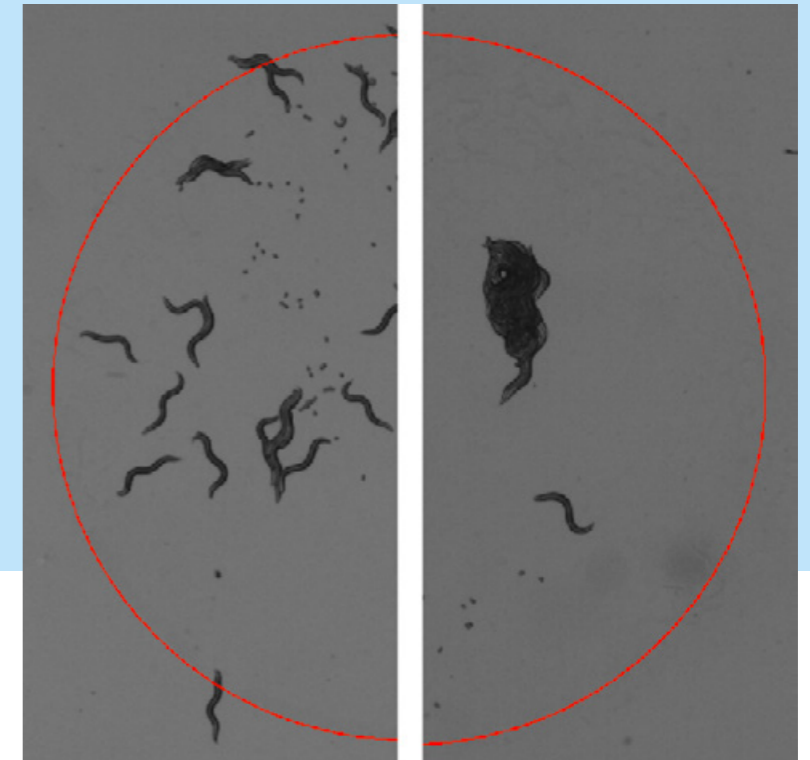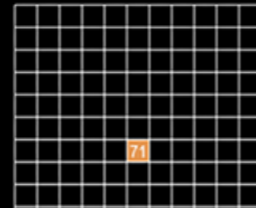
Recent developments in imaging and tracking technologies have yielded mechanistic insights into many collective systems, such as schools of fish, flocks of birds, and swarms of insects. Although most work has considered homogeneous groups, biological systems are inherently heterogeneous; individuals within the same group can differ in intrinsic properties or in interactions. The nematode worm *Caenorhabditis elegans* offers the opportunity to experimentally control and measure the genetic and behavioural characteristics of individuals within the group. Importantly, studying the behaviour at the individual and group level for heterogeneous worm mixtures is both relevant and important for understanding the behavioural ecology of these nematodes. Within the project *Individual heterogeneity to collective behaviour in nematodes* we will develop simulation methods to predict the collective motion characteristics of heterogeneous groups, along with appropriate quantitative metrics to describe the behaviour.

Examining the neuronal and physiological basis of social and collective behaviour using virtual environments

Deciphering the function and the meaning of animal social behaviours is difficult, as the interactions are usually complex and may depend on behavioural feedback loops between individuals. Moreover, human intuition about the function and valence of interactions among animals fails in many cases.

In the project *Examining the neuronal and physiological basis of social and collective behaviour using virtual environments*, Alex Jordan and Paul Nührenberg are using animated fish models in virtual environments to break the social feedback loop and examine the meaning of social interactions in African cichlid fish.

"We ask whether multiple species of the shell-dwelling cichlids have a common, conserved 'language' of social behaviours or whether in the course of social evolution novel forms of behavioural communication have evolved," Alex Jordan explains. They extend this inquiry by exploring patterns of neuronal activity in the brains of individuals during these social interactions. In so doing, they want to understand whether the form, in terms of kinematic structure, or the valence, in terms of neuronal encoding, of behaviour has diverged among these species.

"The use of VR is unprecedented in the study of social behaviours in cichlid fish and also unprecedented in the targeted research question about potential species-specific meaning and utilization of social behaviour," adds doctoral candidate Paul Nührenberg. In previous cichlid research, simple 2D animations were used to study the function of visual threat displays. "Although fish VR experiments were successfully used in other social contexts, such as mate

choice, no previous study used VR to investigate the effects and functions of all behaviours in the social repertoire of one species or even in cross-species comparisons," adds Nührenberg. "Therefore, in addition to answering our scientific questions, we want to advance the realism and interactivity of VR (or similar) playback experiments in behavioural biology."

This novelty is what excites biologist Alex Jordan the most: "Before we started, we knew that our study species are likely to be responsive to images and videos of conspecifics. But our virtual fish, based on scans and behaviours of real fish, also has the capacity to respond to the behavioural output of a live fish, vastly increasing our ability to explore the meaning of social behaviours. More exciting still is that we have been able to deploy these virtual experiments in field settings at Lake Tanganyika." New CASCB postdoctoral researcher Noori Choi shares this enthusiasm: "Seeing the first interactions between a wild fish and a virtual conspecific was an incredible moment," he says.
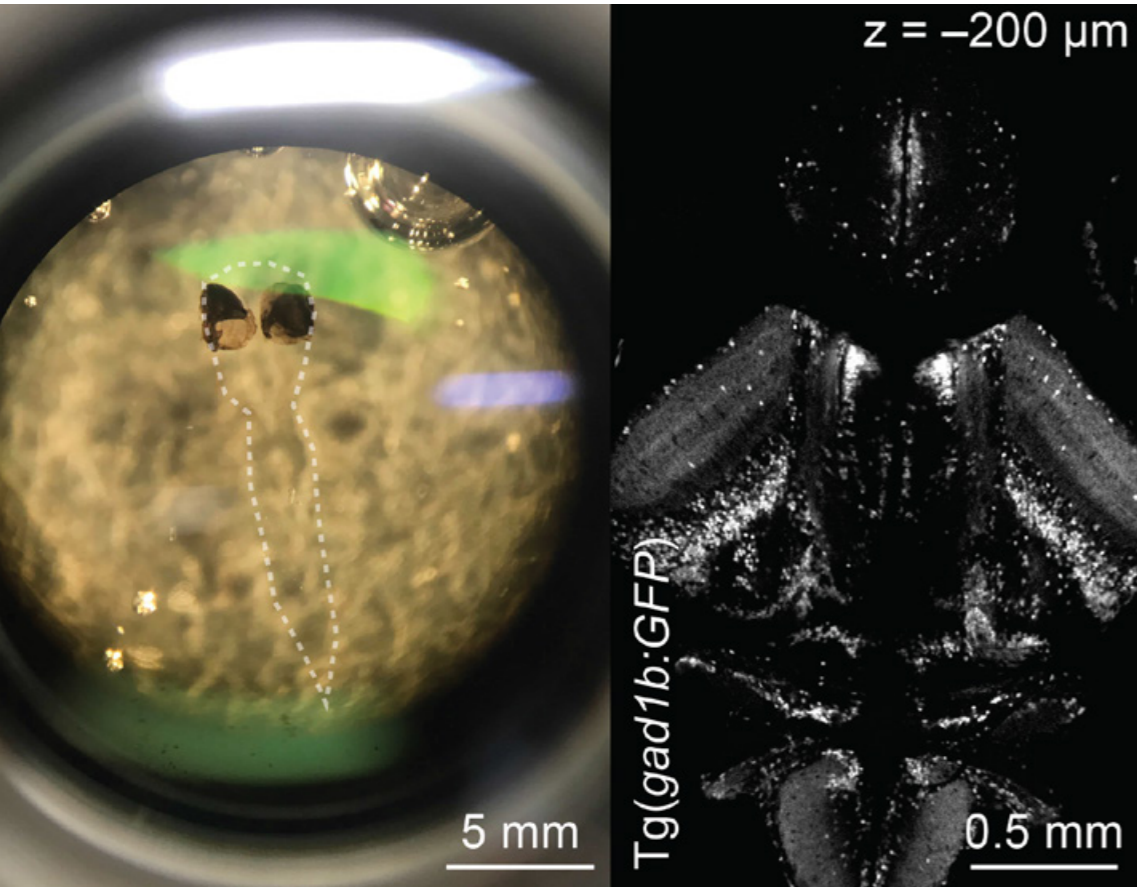
From neural dynamics to individual and collective behaviour in zebrafish

There is a rich history of the study of collective animal behaviour in a wide range of species, including insects, fish, birds, and primates. A major bottleneck in many of these studies has been that the pathways of communication are not directly observable. Hence, how communication occurs must be inferred from dynamic relationships such as spatial associations among individuals. However, while spatial relations indeed inform interactions between individuals, they do so indirectly, through an individual´s detection of sensory cues or signals.

Recently, the focus is shifting from phenomenological descriptions of the interactions between individuals to explicitly considering how organisms acquire and integrate sensory information during behavioural decision-making. To deepen this new perspective, the project *From neural dynamics to individual and collective behaviour in zebrafish* led by Armin Bahl develops new cutting-edge tools to study collective behaviour in immersive virtual reality and lay the groundwork to combine these methods with functional imaging of nervous system activity.

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

Giovanni Galizia and his team study social interactions in the vulnerable raptor Montagu's harrier in Spain. Specifically, in La Serena (southwest Spain), where they find most of the individuals living in colonies. The researchers aim to understand how they interact within and between colonies. They therefore use a combination of visual observations during fieldwork: bird tagging, camera trapping, and nest monitoring, partly by drones. "We tagged juveniles for the first time in 2021, using ICARUS tags," says Giovanni Galizia. Six out of nine juveniles reached their migration sites south of the Sahel. "The aim was to study how they would disperse when returning to Spain, but a halt to collaboration with the ISS because of the Ukraine war terminated data transfer." That is why the team marked 11 juveniles with other tags this year. The researchers obtained information about movements during the dependency period and thereafter, but predation and heat exhaustion caused high losses. "We also obtained information about one adult female starting a second breeding attempt and a male providing food to two females during the same period," highlights Giovanni Galizia. This was the most unexpected research finding for him.
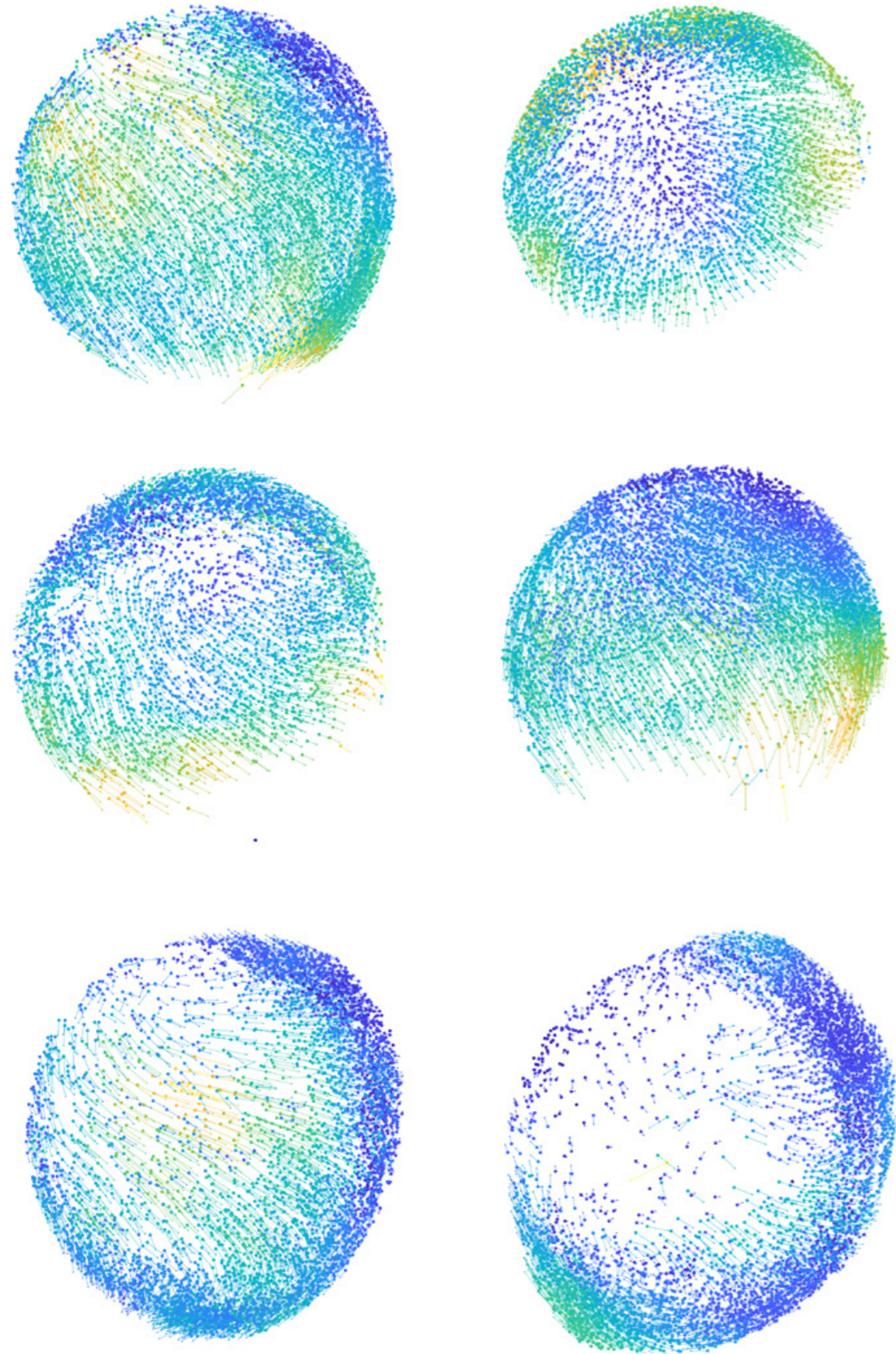
*Collectively moving cells
in zebrafish embryos at
various stages of development*

Newcomer Project

Quantitative imaging and modelling of signalling and mechanics to understand collective cell migration during zebrafish development

Patrick Müller

Cellular communication and mechanical forces are crucial to guiding tissue morphogenesis during animal development. But how cell signalling, mechanical forces, and tissue morphodynamics are coupled during embryogenesis is still an open question. By combining light-sheet microscopy, bioimage informatics tools, and active matter physics concepts, we aim to understand how collective cell migration emerges from the coupling of cell signalling and mechanical forces in zebrafish embryos. We will first generate a multidimensional atlas of zebrafish development to obtain an accurate 3D digital representation of individual cells and their signalling activities over time. We will then use deep learning and statistical techniques to extract descriptors of cell morphology, collective dynamics, signalling, and mechanical forces from the digital atlas. Finally, we will use the quantitative data obtained from the digital atlas to build a model of zebrafish embryonic morphodynamics based on the active matter theoretical framework. The resulting model of collective cell behaviour will be validated using perturbations of signalling and morphogenesis. Together, this approach will allow us to determine how the dynamic coupling of cell behaviour, signalling, and mechanical forces orchestrates collective cell migration during development.
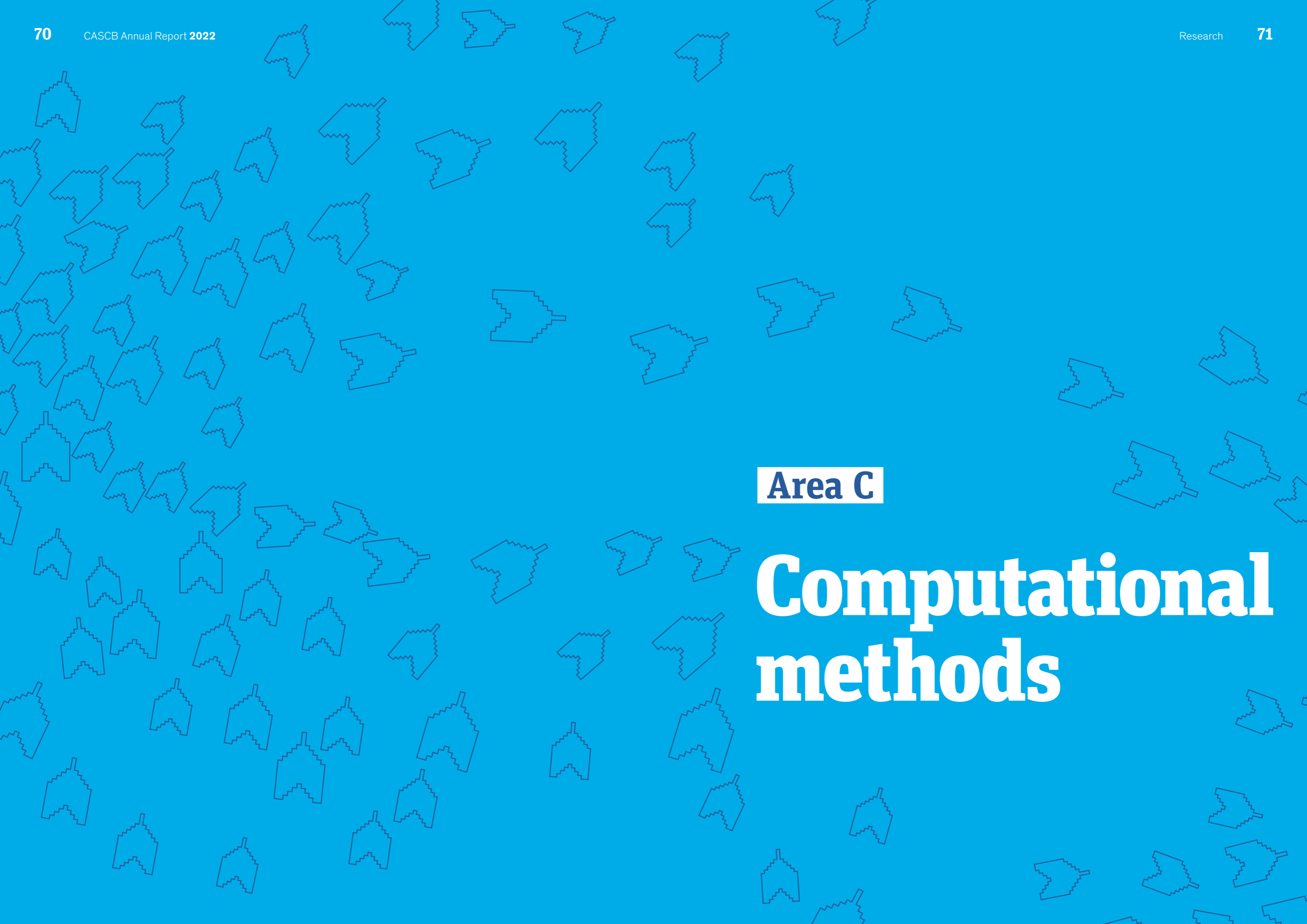
Area C

Computational methods

Low-latency field and laboratory analyses of primate feeding competition in a remote Central African tropical forest

Landscape at Bouamir, Cameroon; the location of the recently completed pilot study for this project.

When Edward McLester is conducting his research, getting to the "office" usually involves some combination of a six to eight-hour hike, a short charter flight, or even a canoe trip. To be precise, he works in the remote tropical forests of Central Africa. But even there, too, the research data generated should be collected and secured and ideally evaluated promptly. Postdoctoral researcher Edward McLester is therefore especially interested to see "how far we can push current technology to help with our data collection workflow," he says. "Researching these kinds of technologies, taking them out to a very isolated site, and then successfully implementing them to get the data 'flowing' back to the office where they can be analyzed, is very rewarding."

In 2022, he and his project collaborator, Kathrine Stewart, received a CASCB Small Grant for the project *Low-latency field and laboratory analyses of pri-mate feeding competition in a remote Central African tropical forest*.

"Among primates, few studies have investigated how interspecific feeding competition influences collective behaviour," Edward McLester explains. Analyzing movement and feeding data concurrently at remote field sites without internet or cellular signals is also limited. "We are collecting fine-scale movement and nutritional data to investigate feeding competition between apes and monkeys across the Congo Basin. We are also reducing latency between data collection and analyses by using satellite data connections to upload data directly from the field to a cloud server for dissemination." Specifically, he and his field teams are using GPS devices to record primate movements and feeding trees.

Edward McLester reports that they upload tracks and tree locations daily to their cloud server, from which collaborators in the laboratory can analyze the energy and macronutrient content of fruit from conspecific samples already housed at the MPI-AB. They will then model primate movements against monkey-ape dietary overlap and feeding tree proximity and nutritional content.

The teams recently completed a two-month pilot at the Bouamir study site in the Dja Faunal Reserve in Cameroon. This pilot allowed them to trial their smartphone data collection protocol in conjunction with a fixed satellite internet connection that was already in place at the research camp. "We considered the pilot a success – both the smartphone app and protocol we developed worked well, and the server we have built on the Max Planck cloud service was fully usable," he says. "We are now in a much better position to know what to expect when we set up an improved protocol for our full-length data collection at the beginning of 2023."

Moustached Monkey

Putty-Nosed Monkey
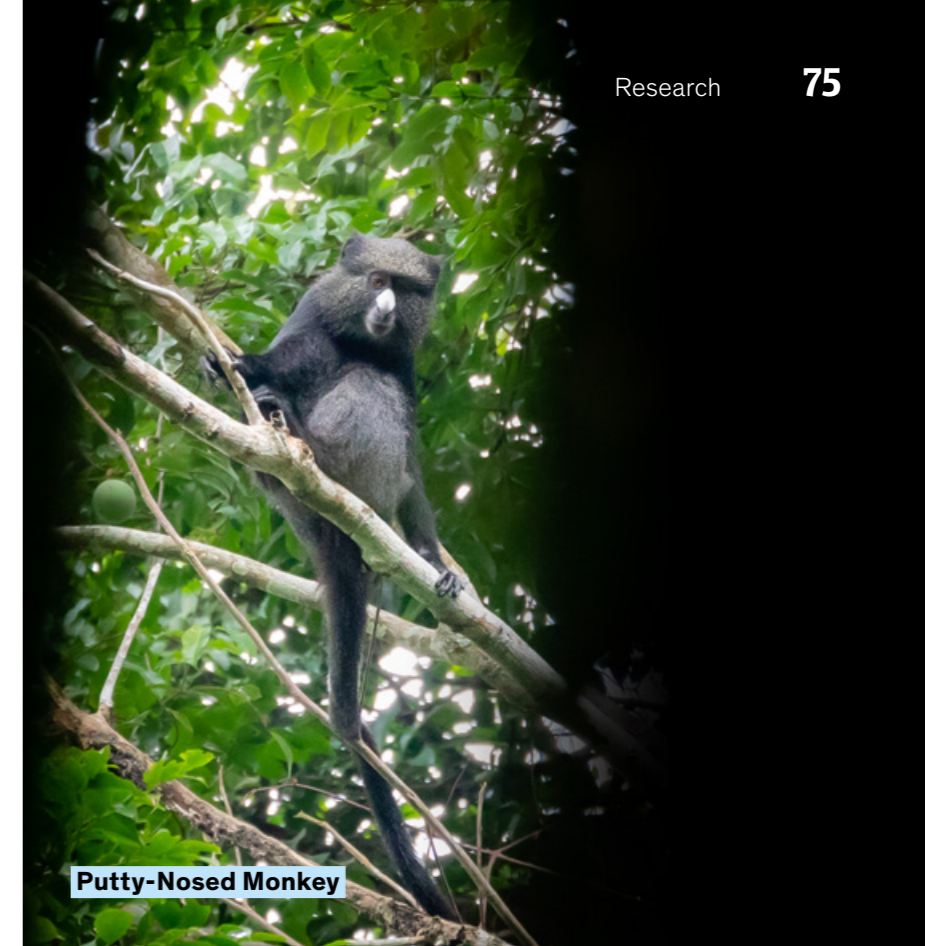
Grey-Cheeked Mangabey

We carried out our pilot study in the Dja Faunal Reserve, Cameroon – a bio-diversity hotspot for primates that is home to at least nine species of diurnal monkey and not one but two species of great ape (both chimpanzees and Western Lowland gorillas). Across this diversity of species are primates that inhabit every type of vegetation (from cryptic Allen's swamp monkeys that are buried deep within riverine areas to chimpanzees that cross savanna clearings), canopy stratum (from mandrills that travel almost exclusively terrestrially to guenons that rarely touch the ground), and dietary niche (from gorillas that consume vast quantities of folivorous vegetation to agile mangabeys that prey on gazelles and other mammals). Choosing an appropriate study species was therefore an initial challenge facing our team. In the end, we focused on three species of arboreal monkey – moustached monkeys, putty-nosed monkeys, and grey-cheeked mangabeys (pictured clockwise from top-left). These monkeys are all social and live in groups of around ten to thirty individuals. We were able to find monkey groups relatively close to the research camp, meaning we could follow groups from sunrise to sunset to have the best chance of recording GPS tracks. Although we lack detailed dietary data, these three monkeys feed predominantly on fruit, followed by insects, flowers, and leaves. Because fruit are relatively patchily distributed across the forest, this allowed us to track groups from fruit tree to fruit tree, providing us with a map of travel routes to analyze that reflect how groups travelled between sources of food. All three of these monkey species also frequently travel and forage together, which provided us with an interesting secondary avenue of research: How might individuals of different species collectively decide on group movements and move together to navigate their forest environment?

The fixed satellite internet connection (pictured right) in place at Bouamir allowed us to pilot a full mobile data collection protocol. Specifically, we used the Open Data Kit suite of tools, which is free and open source. The software comprises a smartphone app and a server that can be hosted on various cloud platforms. Forms (essentially questionnaires) are highly customizable and consist of questions of various types (e.g. entering text or numbers, selecting from a multiple-choice list, etc.) that a user swipes through sequentially in the app. Completed forms are stored locally on the smartphone and can also be uploaded to a server over the internet, where they are automatically organized and compiled into spreadsheets for download and analysis.

To collect data and help expedite the training of local researchers who were not familiar with smartphones, we used the Open Data Kit smartphone app. In the example below, the form presents a multiple-choice question as to which primate species the observer has encountered. Choices are presented in the French and Baka languages, and the red asterisk denotes that the user cannot progress without providing an answer, to stop inadvertent skipping of questions. Completed forms were then uploaded daily via satellite internet to a secure server hosted by the Max Planck Institute of Animal Behavior, where collaborators in both Konstanz and California were able to "stream" data in near-real time for rapid analysis.

This project highlights the importance of involving local collaborators and researchers in wildlife behavioural research. We were only able to collect the data from our pilot thanks to the tireless work of Cameroonian graduate students Forgu Gabriel and Michael Offono and Baka community members Linda, Brice, David, Rémi (pictured left), and Élit (pictured above); the knowledge and experience of whom was paramount to finding monkey groups and recording fruit tree species. Local community members are always the most important stakeholders in this kind of behavioural and conservation research, and we placed a firm emphasis on having local researchers lead and manage data collection.

Mating ecology of a lek-breeding antelope

Lekking is a visually spectacular and extremely rare phenomenon in which males engage in intense displays on closely clustered territories and females visit these territories for the sole purpose of mating. On leks, local interactions between individuals — male-male competition and mate-choice copying in females — contribute to skewed mating success at a global (lek) level. Despite decades of research on various lekking systems, we have little mechanistic understanding of these local interactions in the context of mate choice. The researchers in this project, Vivek Hari Sridhar, Hemal Naik, and Akansha Rathore, therefore argue that the insights from collective behaviour studies can prove to be crucial in understanding mate choice on leks as an emergent phenomenon.

The project *Mating ecology of a lek-breeding antelope* focuses on studying the mating interactions and emergent mating success patterns on blackbuck *(Antilope cervicapra)* leks in the context of the social landscape in which individuals are embedded. To do this, the research team uses multiple Unmanned Aerial Vehicles (UAVs) simultaneously and deep learning algorithms to obtain continuous, fine-scale data of every individual in the lek throughout the lekking season (a few weeks).

In 2022, the researchers completed a pilot field season and collected high-resolution videos covering the entire lek arena. "We witnessed the formation of a new lek near the traditional breeding ground," they say. "Therefore, in phase two of our project, we are formulating the spatially explicit models of lek formation. We intend to test these models with satellite data and finally with the processed high-resolution videos that we will collect in the next field season." To convert these videos into data, the team is

developing methods to spatially register an area of interest, temporally align the videos collected from multiple drones, and finally obtain the movement trajectories of all the individuals as global coordinates.

By quantifying the spatial and temporal dynamics of local interactions, the team will unravel structural and social drivers of mating success in this unique and yet under-explored mating system. In the process, the researchers are also creating a rich dataset and tracking methods which will facilitate a dialogue between biologists and computer scientists and lay foundations for future collaborations.

"Going further, we plan to disentangle theoretical and computational frameworks to various mechanisms that contribute towards lekking dynamics," they say. "Such methods in combination with high-resolution aerial imagery covering movement and interactions on the whole lek will shed light on the drivers of sexual selection in lekking systems."
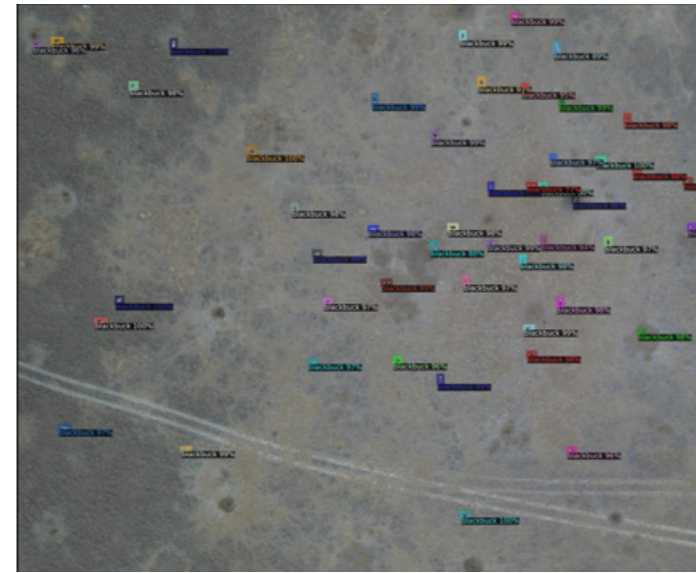
" The primary motivation for pursuing this project comes from our common commitment towards developing research projects in India, our home country. This project allows us to create long-term collaborations and draw attention towards rare and underexplored study systems in India. While the project is scientifically very exciting – to our knowledge, the first study of mating dynamics in leks in a spatially explicit manner – it also allows us to engage closely with local communities and contribute to field-based research while not engaging in parachute science."

Research team:
Vivek Hari Sridhar, Hemal Naik, and Akansha Rathore
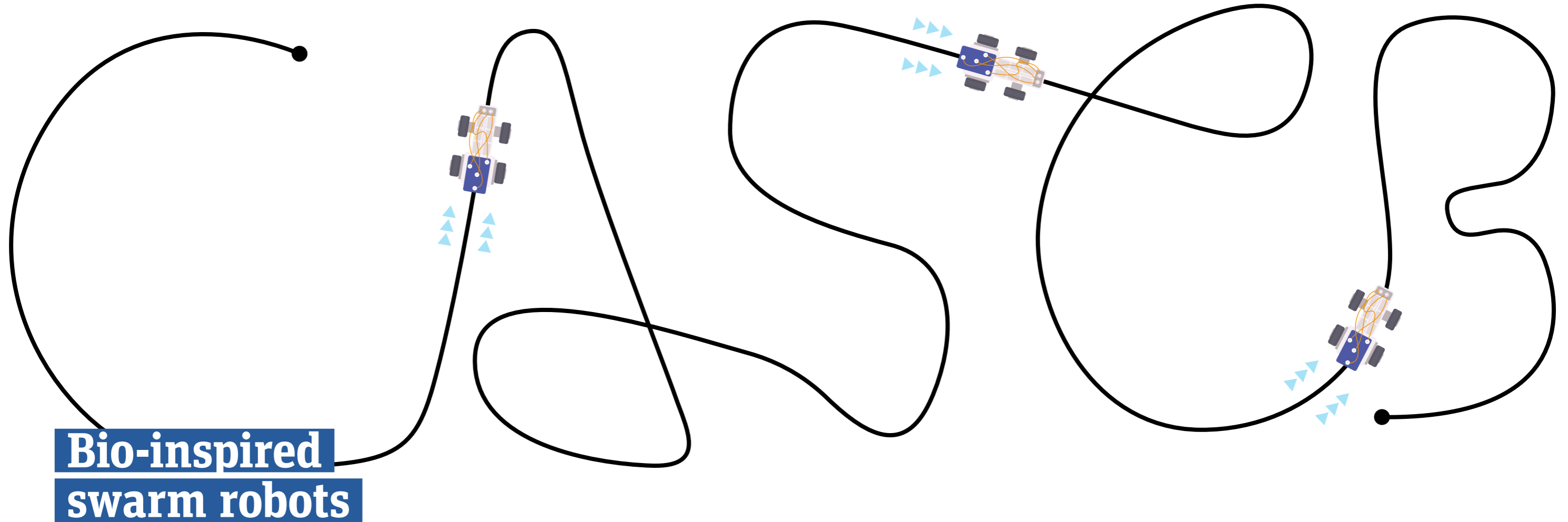
Bio-inspired swarm robots

"Swarm robotics is one of the main applications of collective animal behaviour studies," says Liang Li. It is designed to solve the tasks that are difficult for individual robots to achieve. However, most current studies on swarm robots mainly solve artificial questions, such as asking a group of robots to swim in a circle or over a thousand robots to line up in a starfish pattern. Moreover, the algorithms and parameters for swarm robots are largely optimized on the basis of simplified mathematical modelling.

As a result, swarm robots that are extensively inspired by collective animal behaviour are still largely unexplored. In the project *Bio-inspired swarm robots*, Liang Li and his colleagues constructed a platform of swarm robots to apply algorithms extracted from animal systems. "We applied the sensory motor control of leader-follower behaviour to robots and demonstrate the powerlessness of the biological controller," Li explains. For him, the main innovation is the ability to extract the biological controller and apply it to robotics directly. "With this, we can quantify the control performance. It helps us to understand why the life system evolves out of this control strategy," he says.

The platform has also been utilized in Liang Li's semester course *Biorobotics*, and a general testbed which will help generate and test hypotheses in collective animal behaviour will soon be up and running.

Drone-based observations of wild Indian wolves: a first step towards understanding collective processes in social carnivores

In recent years, we have made significant progress in understanding the principles of collective behaviours and the effects of heterogeneity on collective processes. However, despite the high interest shown by researchers, a quantitative scientific understanding of collective processes in social carnivores is significantly lacking, mainly due to the unavailability of fine-scale movement data. The data deficiency arises from the limitations in tracking and observing social carnivores. In the project *Drone-based observations of wild Indian wolves: a first step towards understanding collective processes in social carnivores*, Adwait Deshpande will capitalize on a rare opportunity to study collective behaviours in a unique population of Indian wolves. His goal is to investigate how social and environmental factors influence the collective movements of the pack. Adwait Deshpande says: "This study, which will start with the data collection in January 2023, will probably be one of the first to extend our quantitative understanding of collective behaviours in wild social carnivores. It will potentially have direct implications for the management of the social carnivore species worldwide."

Newcomer Project

Foundations of imitation learning

Tobias Sutter

The research project *Foundations of imitation learning* aims to develop a statistically principled approach for specific machine learning problems, studying how to learn a task based only on demonstrations represented by trajectories of correlated data that are provided by experts.

Building on the proposed framework for imitation learning, this project will develop optimization-based algorithms that fundamentally contribute towards understanding observed behaviour in a data-driven and mathematically rigorous manner. We plan to verify and test the developed methods and algorithms in specific projects in interdisciplinary collaboration within the CASCB.

CULTURE OF COLLABORATION

→

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

7.3.2022

Laura Nenzi
A logic-based approach to specify, monitor, and learn (spatio-)temporal behaviours

Laura Nenzi presented the spatio-temporal logic STREL and its expressivity to specify and monitor spatio-temporal behaviours over complex dynamic and spatially distributed systems. She then showed how the logic can be used for automatic feature extraction from spatio-temporal data. Finally, she demonstrated the effectiveness of the approaches on case studies from diverse domains, such as urban transportation, epidemiology, green infrastructure, and air quality monitoring.

24.1.2022

Helen McCreery
Problem solving and dynamic control in self-organized collectives

Helen McCreery presented her research, which combines field experiments and mechanistic modelling, on the mechanisms and consequences of collective intelligence in groups of ants.

31.1.2022

Hanja Brandl
The consequences of stress in social groups of birds

Hanja Brandl explored how experimentally induced mid-term chronic stress affects the dynamics and performance of social bird groups.

7.2.2022

Joint talk:
Zukunftskolleg Herz Fellows

Mahsa Mozafary

Bounds for the path vertex cover problem via graph colouring
Star colouring and defective colouring are two types of vertex colouring that appear to be connected to the concept of path vertex cover problems. Mahsa Mozafary is investigating these colourings on certain graph classes to learn more about the relationship between these two problems.

Anteneh Getachew Gebrie

Decentralized accelerated algorithms for hierarchical optimization problems
Anteneh Getachew Gebrie presented two new inertial accelerated algorithms, incremental and parallel computation-type algorithms, involving combinations of proximal, conjugate gradient, and Halpern iteration methods.

28.3.2022

Irene Giardina
The statistical physics of flocks and swarms

Flocks and swarms represent iconic examples of living active matter, where motile interacting individuals give rise to emergent global patterns. Despite the great complexity of their biological components, these groups obey robust statistical laws and can be described within a statistical physics approach. In her talk, Irene Giardina reviewed our current understanding of these systems.

11.4.2022

Vlad Demartsev
Conversational dynamics in social mammals

Vocal signalling plays an important role in the mediation of animals' activities. Once considered as rigid and innate, we are now witnessing rapid accumulation of evidence that supports the flexibility of vocal production in animals, as Vlad Demartsev showed on his study species, the meerkats.

25.4.2022

James Foster
The honeybee's polarization compass – dance away the indecision

Honeybees rely on skylight polarization as part of their solar compass system. To date, it remains unclear how this information is integrated. One overlooked factor may be the influence of sensitivity, signal strength, and estimated reliability on the weighting of each region in this process, as James Foster argues.

2.5.2022

Jörg Henninger
Brain-wide mapping of auditory evoked responses in the small, transparent teleost fish

Jörg Henninger and his colleagues recently introduced a novel model organism, the teleost fish *(Danionella cerebrum)*, for monitoring brain-wide activity at a temporally and spatially high resolution.

9.5.2022

Alison Barker
Notes from underground: vocal communication in the naked mole-rat

Recent work from Alison Barker's research group identified a critical role for vocal communication in naked mole-rat societies.

19.5.2022

Stephanie King
Communicative and cognitive mechanisms underlying multi-level dolphin alliances

Stephanie King demonstrated that bottlenose dolphins are a valuable model system for understanding the evolution of polyadic cooperation between non-kin.

30.5.2022

Jeanine Grütter
Understanding and shaping group dynamics in heterogeneous classrooms

Jeanine Grütter presented research on the development of peer relations among children and adolescents, highlighting the role of teachers for their students' social and moral competencies and social inclusion.

20.6.2022

Anna Stöckl

Hawkmoth neuroethology – from flower inspection to pattern recognition

Anna Stöckl presented data from current projects on the role of patterns for flower inspection, which demonstrate that hawkmoths use patterns to guide their proboscis towards the nectary of a flower using visual control.

4.7.2022

Simon Garnier

The self-assembling horde: building functional structures on the move

Simon Garnier presented recent findings on the principles that govern army ant self-assembling into complex, dynamical, and functional structures.

11.7.2022

Johannes Larsch

Neurogenetics of social affiliation in zebrafish

Johannes Larsch's research group investigated affiliation pathways in juvenile zebrafish in the context of shoaling, the innate and perpetual drive to swim in groups with continuously moving conspecifics.

18.7.2022

Sonja Wild

When, who, and what to copy – dynamic learning strategies in wild birds

Sonja Wild presented the development of social networks and learning strategies in great tits *(Parus major)* during ontogeny.

31.10.2022

Akanksha Rathore

Mating ecology of a lek-breeding antelope – blackbuck

Akanksha Rathore presented research on the effect of local interactions between individuals on mating success in the blackbuck *(Antilope cervicapra)* population.

7.11.2022

Joint talk: Zukunftskolleg Herz Fellows

Diego Morales

On modelling and estimating geo-referenced count spatial data with excessive zeros Diego Morales proposed a new approach on how to model spatial count data with excess zeros.

Yuqi Zou

Social learning strategies in budgerigars' foraging behaviours Yuqi Zou researched the effects of age and number of tutors on social transmission of foraging information and the trade-off between personal and social information in budgerigars *(Melopsittacus undulatus)*.

14.11.2022

Miya Warrington

Variation in cooperation and social organization in a non-aggressive ground squirrel

Miya Warrington discussed the variation in social associations and behaviours of Cape ground squirrels *(Xeris inauris)* and how these affect fitness and survival, thus contributing to the maintenance of social living in this species.

18.11.2022

Yuko Ulrich

Behaviour and disease in clonal ant societies

Yuko Ulrich is the first recipient of the new research award of the Zukunftskolleg at the University of Konstanz. The biologist studies the spread of diseases and disease resistance in social insects. During her talk, she gave an insight into behaviour and disease in clonal ant societies.

28.11.2022

Michael Grossniklaus

Why you should care about query optimization in databases

Michael Grossniklaus discussed how database research into query optimization has addressed the problem of efficiently and effectively providing answers to practitioners in the context of relational databases.

5.12.2022

Tim Johnson

Prime numbers and the evolution of cooperation

Tim Johnson presented research on the influence of prime numbers on the evolution of cooperation.

12.12.2022

Dana Galili

Generating parallel representations of position and identity in the olfactory system

Dana Galili discussed the use of separate neuronal processing streams in Drosophila to extract qualitative and positional information from the cVA pheromone.

19.12.2022

Andreas Thum

From structure to function: what we can learn from the connectome of the Drosophila larva

Andreas Thum presented research on the mushroom body of Drosophila larva and how it is used to achieve a nuanced account of molecular function in a behaviourally meaningful memory network.

Spring Retreat

→ **4-6 APRIL 2022**

The CASCB held its first retreat of 2022 on campus at the VCC Data Theatre on 4-6 April. The focus was on providing the cluster community with ample opportunity to meet in person, discuss and present ideas, and re-connect after a period of extensive social hiatus due to COVID-19.

As a special treat, two members of the CASCB Scientific Advisory Board, Karl Sigmund from the University of Vienna and Jutta Schneider from the University of Hamburg, joined the retreat. Both delighted us with inspiring plenary presentations, as did cluster members Armin Bahl and Andrea Flack.

→ **The neural basis of zebrafish decision-making**
    (Armin Bahl, CASCB/University of Konstanz)
→ **Understanding collective migrations**
    (Andrea Flack, CASCB/Max Planck Institute
    of Animal Behavior)
→ **Adaptive dynamics of signalling games**
    (Karl Sigmund, University of Vienna)
→ **Cooperative foraging in group-living spiders**
    (Jutta Schneider, University of Hamburg)

Further food for scientific discussion was provided in the form of posters and spontaneous talks (courtesy of Barbara Fruth, Jacob Davidson, Karl-Philipp Flösch, and Michael Chimento).

Also popular were the guided tours of the Imaging Hangar (courtesy of Mathias Günther) and spontaneous demonstrations and workshops on Motion Capture (Urs Waldmann), the Handling of Inherited Code (Thejasvi Beleyur), and the Creation of a Network for Female ECRs (Katrin Vogt). A convivial CASCB community added to the enriching atmosphere by initiating social get-togethers and offering homemade culinary specialties.

The retreat closed with the annual meeting of the CASCB General Assembly and an afternoon workshop with a visiting delegation of design students and academic staff from the Merz Akademie, leading to the wonderful *Documentary Palaces* exhibition in December 2022 in the university's foyer.

In retrospect, the Spring Retreat was also very successful in inspiring and laying the groundwork for future cluster projects and collaborations.

Autumn Retreat

→ **11-13 OCTOBER 2022**

The CASCB held its second retreat of the year on 11-13 October at the beautiful lakeside venue of Schloss Marbach. Firstly, this retreat marked the moment of being able to get together again in person, hence the effort put into selecting a truly beautiful and inspiring location. Secondly, it marked another milestone in that one of the tasks was to take a first look into the future and the research directions the cluster might put forward in its upcoming renewal application to the German Research Foundation, which is to be submitted in 2024. The prospect of setting the course for the future also gave rise to the need to reflect on the status of implementation towards the original cluster goals and the lessons learned since 2019.

With an impressive set of goals and 100 participants in total as the baseline, the Autumn Retreat could not have set off in a more exciting and promising way, nor was the programme anything less than ambitious. In wise anticipation of intense intellectual and conceptual sessions, the cluster office team joined forces with a professional workshop facilitator, Martin Lengefeld. With Martin's invaluable help, the organizing team eventually moulded all goals into a three-day agenda. The resulting programme consisted of inspiring scientific talks, productive thematic workshops in varying group compositions, poster sessions, creative walks, and time for free scientific exchange. Of course, other mind-nourishing pleasures, such as joint meals with excellent food and fun social activities, were not neglected either.

Three cluster newcomers and one visiting member of the CASCB Scientific Advisory Board gave very interesting plenary talks on:

→ **The bonobo behavioural ecology project and its intersection with the CASCB**
(Barbara Fruth, CASCB/Max Planck Institute of Animal Behaviour)

→ **Decision-making, human-swarm interaction, minimize surprise**
(Heiko Hamann, CASCB/Uni Konstanz)

→ **Perception of energy, uncertainty, and the integration of options in movement decisions**
(Hannah Williams, CASCB/Max Planck Institute of Animal Behaviour)

→ **The quest for a biological concept of beauty**
(Leonida Fusani, Konrad Lorenz Institute of Ethology, University of Veterinary Medicine, Vienna/Department of Behavioural and Cognitive Biology, University of Vienna)

Apart from the talks and introductory remarks on cluster facts and figures, each day was dedicated to a specific set of group tasks and reflections. These followed the retreat's goals of providing room for retrospection while also creating an outlook to future ideas and directions. Depending on the topic, groups were organized either on a project level, vertically assigned by field, or mixed horizontally to yield a good diversity of viewpoints and experiences. After intense discussion in different constellations, results and insights were gathered and shared with the plenary via the retreat's virtual Miro white board. In conclusion, many researchers and project groups could still relate well to a number of the original goals and rate their project's progress against them, whereas other goals seemed to vary in relevance or turned out to be specific only to a limited number of projects and research areas. The results of the first day further indicated the need to reflect on and revise the list of goals in light of the cluster's ongoing development and future common vision in a more concise and unifying way. The second and third days yielded a rich spectrum of future topics assorted by different fields and research interests, some already hinting at common overarching research questions and topics that appeared highly promising for further development.

Thus, maybe most importantly, the community that gathered at Schloss Marbach also came up with a long list of concrete suggestions for the next steps and further initiatives. The cluster office collected all the suggestions and ideas from this highly productive event and will schedule them for follow-up discussions with the cluster committees and decision-making bodies over the next months, with the goal of sharpening and condensing them into concrete structural and research strategy considerations to be incorporated in the future proposal for the cluster's extension.

Courses, conferences, and workshops

Workshop: sensory ecology of collective behaviour

The workshop "Sensory Ecology of Collective Behaviour" sought to combine the considerable expertise relating to collective behaviour that exists in Konstanz with that in sensory ecology of several short-term visitors to the university's Zukunftskolleg, including Amanda Melin, Nate Dominy, and James Higham. With the support of the CASCB, Hannah Williams and Ari Strandburg-Peshkin invited a number of experts in both fields from Germany and Switzerland. During the workshop, the researchers discussed how considering the sensory system of animals facilitates the study of collective behaviour, and conversely how a collective perspective can inform the study of sensory ecology. The two-day workshop culminated in the group writing a joint proposal and outline for a perspective article on the sensory ecology of collective behaviour. Work on the article continued after the workshop, and the group hopes to submit the paper as well as organize a follow-up workshop in the coming year.

Creating agency and cognition in automated systems: What can we learn from the octopus?

Octopuses are intelligent creatures that seem to have multiple and layered cognitive systems that can both act in a uniform way as well as independently from one another. That is why Eduardo Sampaio, Sidney Carls-Diamante, Erwan Renaudo, Andrea Lopéz-Incera, and Maud van Lier proposed the octopus as an inspirational source for the creation of agency and cognition in automated systems in a workshop which took place in May 2022.

Biorobotics course

Despite decades of advancements in robotics, the capabilities of biological systems remain an elusive performance target. One of the difficulties is that we do not fully understand the mechanisms in biological systems. In this course, Liang Li aimed to explain both bio-inspired robotics and how to use these robots to understand biological systems. In the final exam, students had to trace the CASCB name with a robocar they had programmed themselves. The CASCB community was invited to join the event.

Researcher meeting with a delegation from the University of Essex

A CASCB Researcher Meeting with a delegation from the University of Essex was held on 16 May 2022. After a workshop, we offered guided tours to the Bahl lab (courtesy of Max Capelle and Katja Slangewal) and the Imaging Hangar (courtesy of Ahmed El Hady). The event was organized by the International Office of the University of Konstanz and brought to life by the cluster and through fruitful exchange with the visitors. Iain Couzin and the visitors led by Ed Codling organized a successful online workshop in September 2021 ("Collective Systems"). The idea was then to follow up on this workshop and build on the previous discussions.

Guest visitors

Francesca Cairoli from the University of Trieste visited the CASCB in March 2022. She is working on deep learning for abstraction, control, and monitoring of complex cyber-physical systems. During her visit, a one-day workshop on the use of deep learning for abstraction, control, and monitoring of complex system dynamics took place. In addition, individual meetings with cluster members were organized.

DAGM German Conference on Pattern Recognition

The DAGM German Conference on Pattern Recognition (DAGM GCPR) 2022 was the 44th annual symposium of the German Association for Pattern Recognition (DAGM) and took place in Konstanz in September 2022. It was a premier international venue for recent advances in pattern recognition, including image processing, machine learning, and computer vision, and welcomed submissions from all areas of pattern recognition.

COSMOS: Computational Summer School on Modelling Social and Collective Behaviour

Computational modelling is becoming both more important and widely used in behavioural sciences. However, the mathematical framework and computational skills necessary to tackle the interdisciplinary challenges of modelling collective behaviour are not always readily accessible to early career researchers. That is why Wataru Toyokawa proposed a summer school dedicated to developing the skills needed to communicate with researchers of social and collective behaviour from various fields, using computational models as a common language. Forty-four students from many different fields (psychology, cognitive science, economics, neuroscience, evolutionary biology, and computer science) and geographical regions (Europe, America, Asia, and Africa) attended in person. The tutorial materials and the video recordings of the thematic lectures are publicly available online: *cosmos-konstanz.github.io/materials*

International Symposium on Integrative Bioinformatics 2022

We drown in data but starve for knowledge. The 16th Symposium on Integrative Bioinformatics organized by Falk Schreiber aimed to change this. The meeting provided an excellent environment and a range of opportunities to present and discuss methods, theoretical approaches, and their practical applications. For CASCB researchers, the topics "Computational methods for animal behaviour," "Database integration in the life sciences," "Formal modelling of collective systems," "Modelling and simulation frameworks" as well as "Visual and immersive analytics for biosciences" were some of the highlights.

Guest talks

→ Flexibility of an innate social behaviour: from circuit mechanisms to learning, Frederic Roemschied, Murthy Lab (Princeton)/ University of Cologne, 28 June.

→ Social information use in collective foraging, Dominik Deffner and Alan N. Tump, both MPI Berlin, 5 July.

→ Foundations of human joint action, Raphaela Heesen, Durham University, 6 September.

→ Neurocomputational approach to nutrient-based food choices in rhesus monkeys, Fei-Yang Huang, University of Oxford, 19 September.

→ Individual and collective learning in human groups facing danger, Hirokazu Shirado, CMU, 11 November.

Diversity and equity in a year full of growth and expansion

Our cluster welcomes knowledge, expertise, and collaboration from throughout the world, and in the course of 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 often go unheard. This allows us to build a diverse environment where everybody feels welcomed, respected, and appreciated.

In this past year, the cluster community grew considerably and was enriched by excellent new scientists from throughout the world. By consciously diversifying our community, we aim to broaden perspectives and provide a platform for knowledge that might otherwise be missed.

Going unheard is a common feeling among many scientists, particularly ones in underrepresented groups. That is why this year's International Women's Day celebrations on 8 March focused on being heard and speaking out in the science community. The CASCB organized a workshop that aimed to encourage female scientists to communicate and speak out, sharing their unique perspective and in the process becoming a heard and visible part of the global research community in order to build a lasting future in science.

In close cooperation with the Zukunftskolleg of the University of Konstanz, the cluster was able for the third year in a row to host another cohort of ZUKOnnect and Herz Fellows. These fellowships are designed for young scientists from the Global South. They encompass an on-site visit in Konstanz with the local host and an online affiliation. During the on-site visit, the fellows are encouraged to build scientific networks and to strengthen their independence as early career researchers.

To mutually benefit from this exchange, the fellows delivered enlightening insights into career paths in their country of origin in order to raise awareness when recruiting people worldwide. How do applications differ, what are the circumstances and opportunities? For all these questions, the fellows illustrated structural differences and how to take them into account.

In a second step, an interview guideline for conscious recruitment was provided in order to reduce unconscious biases during the recruitment process, starting with the job description and ending with onboarding in the cluster community.

As a bridging concept, intersectionality drives us towards a more equitable work and research environment. The intersections combined in an individual constitute a person's unique perspective and enrich the community as a whole. The Diversity Committee shed light on a few intersections within the "Diversity for Diversity" series, where speakers were invited to share perspectives on gender diversity and racial diversity in German academia. The Diversity Committee seeks to foster the visibility of individual and structural issues which interlink in our community and strives to provide opportunities for an inclusive community of the future.

Outreach

Re-shaping nature exhibition

A Perspex box with speakers sits on a table. By pressing small plates on its left and right sides, light is emitted and sounds are played. Fiddler crabs are set in motion. Real movement data, which the biologist Daniela Perez has collected, are made audible in the art installation by Felina Russ.

On 13 May, the *Re-shaping nature* exhibition opened at the CASCB and we were thrilled: 70 people attended the vernissage! Students at the Merz Academy, University of Applied Art, Design and Media, Stuttgart, visualized scientific movement data. The bandwidth of the results ranges from animated posters to virtual reality installations.

The semester project *Re-shaping nature* focused on artistic experimentation with data. The basis for the art objects were movement recordings of various animal species. Hemal Naik initiated the collaboration: "For me, art and science are two sides of the same coin. We wanted to create a platform on which both sides can interact and work together." The goal was achieved, as Jörg Frohnmayer, a member of the scientific and academic staff at the Merz Academy, says: "In the *Re-shaping nature* project, the interdisciplinary exchange of students and doctoral candidates created a platform that offers researchers an opportunity to reflect on their work, integrates students into a real context, and makes highly specialized research work accessible to a broad audience," summarizes Mario Doulis, professor at the Merz Academy: "The lively exchange and the valuable feedback throughout the entire project were critical to its success, which is reflected in the quality of the displays at the final exhibition."

And the researchers also benefited, as Daniel Calovi assures: "Originally, my simulations were two-dimensional. It was great to see how a similar swarm would behave in 3D and be able to interact with the swarm in real time."

Documentary Palaces

While the visualization of (scientific) data and information has become a well-developed part of any graphic and media designer's repertoire, the design of a comprehensible documentation and representation of a whole field of knowledge is often the result of individual and complex standalone solutions. That is why a semester course at the Merz Akademie hosted by Joost Bottema, Mario Doulis, and Jörg Frohnmayer focused on this aspect. Like in the project *Re-shaping nature*, the art students worked, once again, with data from the CASCB and the MPI AB. This time, Blair Costelloe shared her knowledge and research data from her *Herd Hover* project.

Goal and approach of the project

The goal was to develop artistic approaches for the design of knowledge spaces within the field of animal behaviour science. Besides the visualization of the related scientific data and documents, the course leaders and students curated the arrangement of the content, revealing the "big picture" and/or a unique substory line. The title "Documentary Palaces" refers to the terms "documentary theatre" (using pre-existing material as source material for stories about real events) and "memory palace" (a memory enhancement strategy using visualizations of familiar spatial environments to enhance the recall of information) which serve as the design base for this project.

Gratifying collaboration

"I have really enjoyed the collaboration with the Merz Akademie and been impressed by the creativity and professionalism of the students," says Blair Costelloe. "It has been very gratifying to share my work with this group and see my project anew through their eyes. Our meetings have sparked fascinating discussions on diverse topics, including the ethics of developing novel data collection methods, the emotional experiences of animals, and what we can and cannot learn about our own species from observing animal behaviour. I am happy that my research has been able to inspire such interesting projects and hope that the projects in turn inspire others to explore the overlap between science and art."
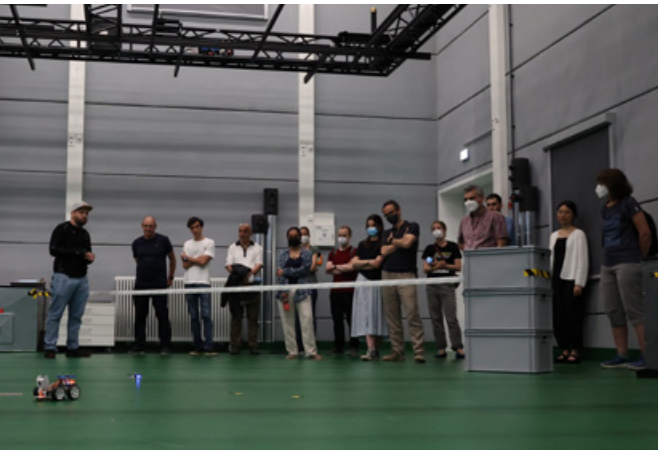
On 2 December we showed the project results in the *Herds and Hovering* exhibition at the University of Konstanz in the Foyer.

Read more:

exc.uni-konstanz.de

Science Night 2022

"Participate!" was the motto of the Science Night 2022 in Konstanz and Kreuzlingen. People of all ages were invited to come and visit science facilities there. Of course, the CASCB participated in the event, which took place on 14 May 2022.

Booked out

All our tours to the Imaging Hangar, zebrafish lab, and locust facilities were booked out. We were overwhelmed. We gave our visitors an insight into the following labs:

→   What makes a locust swarm?
(lab members of the Einat Couzin-Fuchs lab)
→   Behaviour and neurobiology of zebrafish decision-making (Armin Bahl)
→   Imaging Hangar (Mathias Günther, Liang Li, Ahmed El Hady)

Making decisions

How do animals decide? An interactive experiment by CASCB doctoral candidates (Katja Slangewal, Stefan Feyer, and Kavitha Kannan), where participants experienced that decisions are not easy to make. Great fun for everyone who loves wearing a special hat!

Tracked!

Our doctoral candidate Urs Waldmann presented his tracking system at the main entrance of the university. The visitors were amazed and wanted to learn more about collective behaviour. Some even went straight to the VCC building.

Know-how

Paul Nührenberg showed his VR installation "How virtual fish help us to understand animal behaviour."

Under observation

The Hungry Brain — hunger influences our food choices and shopping decisions. Animals also behave differently when hungry, as Katrin Vogt showed with fruit fly larvae.

Face to face with nature

How does it look and feel to be at eye level with plants? The Health Psychology WG set up a display case filled with plants, where participants could experience first-hand what it is like to be at eye level with nature.

We also showed the stunning collective behaviour photos by Christian Ziegler on the CASCB floor and the *Re-shaping nature* exhibition.

A fantastic science night ended as it gradually grew dark.

Visit from a delegation of the Lindau Nobel Laureate Meeting

On 2 July 2022, the University of Konstanz and the CASCB welcomed a delegation of young chemists who had participated in the 71st Lindau Nobel Laureate Meeting. CASCB group leader Ari Strandburg-Peshkin gave an insight into her research on meerkats: "Let's go! How animals communicate and coordinate on the move"

Visit from the University Council

High-ranking visit to the CASCB: the University Council, the university's highest committee, visited the CASCB on 4 July to hear in detail about the experiments we are conducting in the VCC labs and the Imaging Hangar.
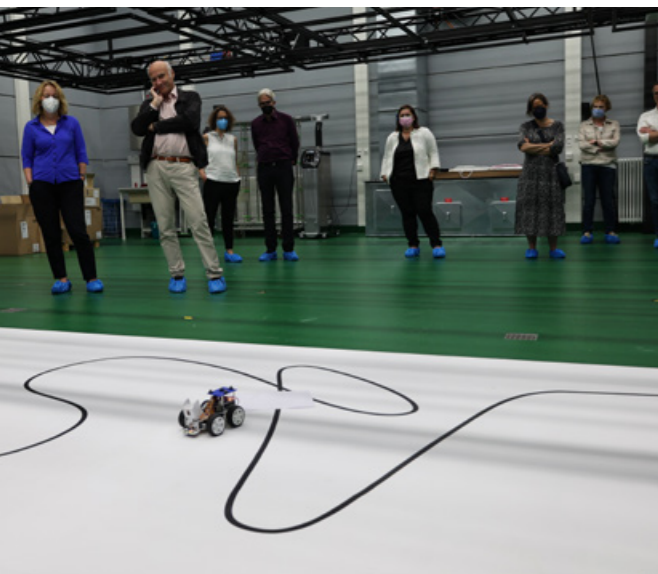
"University Day" is a fixed part of the Hegau-Bodensee Seminar that gives school students the opportunity to conduct research directly with scientists and experience hands-on recent research performed at universities. Supported by lectures, workshops, and excursions, they tackle chosen topics in collaborating working groups.

CASCB researchers were involved in two courses:

➔ "Heart rates synchronization in groups", a workshop lead by the AG Pruessner, including Bernadette Denk, Maria Meier, and Stephanie Dimitroff, Neuropsychology
➔ "Collective behaviour rules!", a workshop by Ahmed El Hady, CASCB

One of the school students provided the following feedback: "Overall, I loved this workshop! I never thought that science could be this interesting, but this workshop really opened my eyes. […] I was super inspired by the passion that the scientists have for their work because that really showed me that your job can actually be fun."

FIELD

Fostering inclusion, equity, and latitudinal diversity (FIELD) is a project led by postdoctoral researchers and funded by the MPI-AB and the CASCB. The project aims to create a space for people to share stories detailing the many intersectional ways that identity can be recontextualized while being a biologist in the field. The hope of the initiator is that readers will find validation in familiar stories, illumination in unfamiliar stories, and confidence that awareness and accommodation can make field biology enriching for all.

Read more:

fieldperspectives.org

Swarm photo event and Advent celebration

For a year now, 13 swarm photos have hung in the CASCB corridor. Time to learn more about the stories behind the pictures. Photographer Christian Ziegler, commended as a wildlife photographer of the year, shed light on them in a photo event on 24 November. He was accompanied by CASCB researchers Barbara Fruth and Edward Hurme. The theme of the evening was food sharing: from the importance of discarding and spreading eaten seeds to preserve ecological diversity to sharing food beyond the family. This is shown in a photo of bonobos eating the fruit of a junglesop tree *(Anonidium mannii)* together.

And what should by no means be missing afterwards? A joint Advent celebration, of course: we concluded the evening with delicious Christmas biscuits and mulled wine. It was also the perfect opportunity to inaugurate our brand-new CASCB mugs. All in all, a great evening with many familiar faces from the CASCB and MPI-AB community.

In the media

Müde Primaten: Wofür Affen ihren Schlaf opfern

Is a monkey's sleep pattern similar to that of a human? National Geographic highlighted the research work of Meg Crofoot and her team from the MPI-AB and the CASCB.

nationalgeographic.de

Deutsches Gesundheitsportal / 8.3.2022

Die Sprache des Auges

The Deutsches Gesundheitsportal delved into CASCB researcher Fuhimiro Kano's research on how the whites of eyes are relevant for communication.

deutschesgesundheitsportal.de

Pro-Physik / 9.3.2022

Physiker entschlüsseln mit Mikrorobotern, wie Tierkollektive effektiv auf Gefahren reagieren.

With the help of microrobots, Konstanz physicists Chun-Jen Chen and Clemens Bechinger decode how swarms of animals respond effectively to danger. Their study was highlighted in the physics portal Pro-Physik.

pro-physik.de

Neuroscience News / 2.4.2022

Examining the Link Between Blood Pressure and Emotions

Researchers at the CASCB have been studying the link between blood pressure and emotions for years and, as Neuroscience News reported, they have found that link.

neurosciencenews.com

Der Spiegel / Wissenschaft / 8.4.2022

Warum Ameisen nie im Stau stehen

Are there common behaviours in animal collectives that can be traced across various species? Can these behaviours be used in human collectives to improve society? Spiegel spoke with Iain Couzin about his research on animal collective behaviour and asked him whether certain markers can be seen in different collectives.

spiegel.de

3sat / NANO / 11.5.2022

Iain Couzin und das kollektive Verhalten von Vögeln

CASCB researcher and Leibniz Prize winner Iain Couzin has not only been captivated his entire life by the beauty of nature but also by the question of how animals and humans interact with each other in collectives. In their profile on Couzin, 3sat Nano talked to him about these local interactions between animals in groups that fascinate him so much.

3sat.de

The Guardian / 2.6.2022

Glyphosate weedkiller damages wild bee colonies, study reveals

The Guardian interviewed Anja Weidenmüller about the huge damage glyphosate has on bumble bee colonies.

theguardian.com

BR / Unkraut - Ihr Umweltmagazin / 2.6.2022

Retten wir so die Bienen?

How bad are pesticides for bumble bees and their environment? Bumble bee expert Anja Weidenmüller was interviewed by Janina Nottensteiner and the environmental magazine Unkraut during their investigation of this question.

br.de

Doch nicht die Schlausten? Was wir von den Tieren und ihren "Staaten" lernen können

Could humans learn how to interact with each other by following in the footsteps of animals? The Salzburger Nachrichten explored this idea and looked at Iain Couzin's research.

sn.at

Der soziale Faktor der Tierwanderungen

Do social factors play a role in animal migration? CASCB researchers have discovered that the answer to this question is 'Yes'. This research was the topic of an article by VBio.

vbio.de

Naturschutz mit KI - Können Computer unserer Umwelt helfen?

Nine ½ presenter Luam visited a very special photo shoot – organized by CASCB researcher Hanja Brandl! The motif was great tits. The birds are photographed for the purpose of training AI.
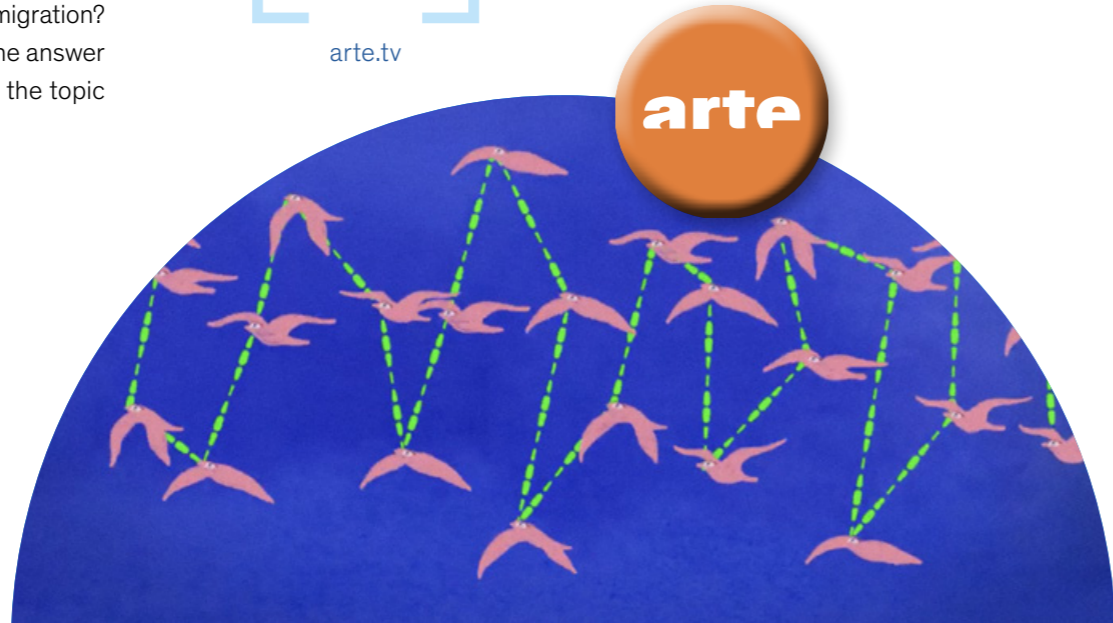
ardmediathek.de

Sind wir im Schwarm intelligenter?

Are we more intelligent in a group? Arte 42 – Die Antwort auf fast alles asked CASCB speaker Iain Couzin and CASCB group leader Einat Couzin-Fuchs this question.

arte.tv

Meine Gesundheit = Meine Entscheidung?

Are things related to health solely up to the individual or is the population as a collective responsible too? This was the topic of the ZEIT DOCTOR Sprechstunde in which Britta Renner took part.

verlag.zeit.de

Wann stechen Bienen zu?

Did you know that honeybees are less likely to sting in larger groups? Morgane Nouvain and Tatjana Petrov's research on the role of group size in a bee's willingness to sting was the topic of an article by MDR.

mdr.de

Iain Couzin honoured as a Highly Cited Researcher

For the fifth time in a row: Iain Couzin honoured as a Highly Cited Researcher. Five questions about the number five with the renowned collective behaviour researcher on campus.kn
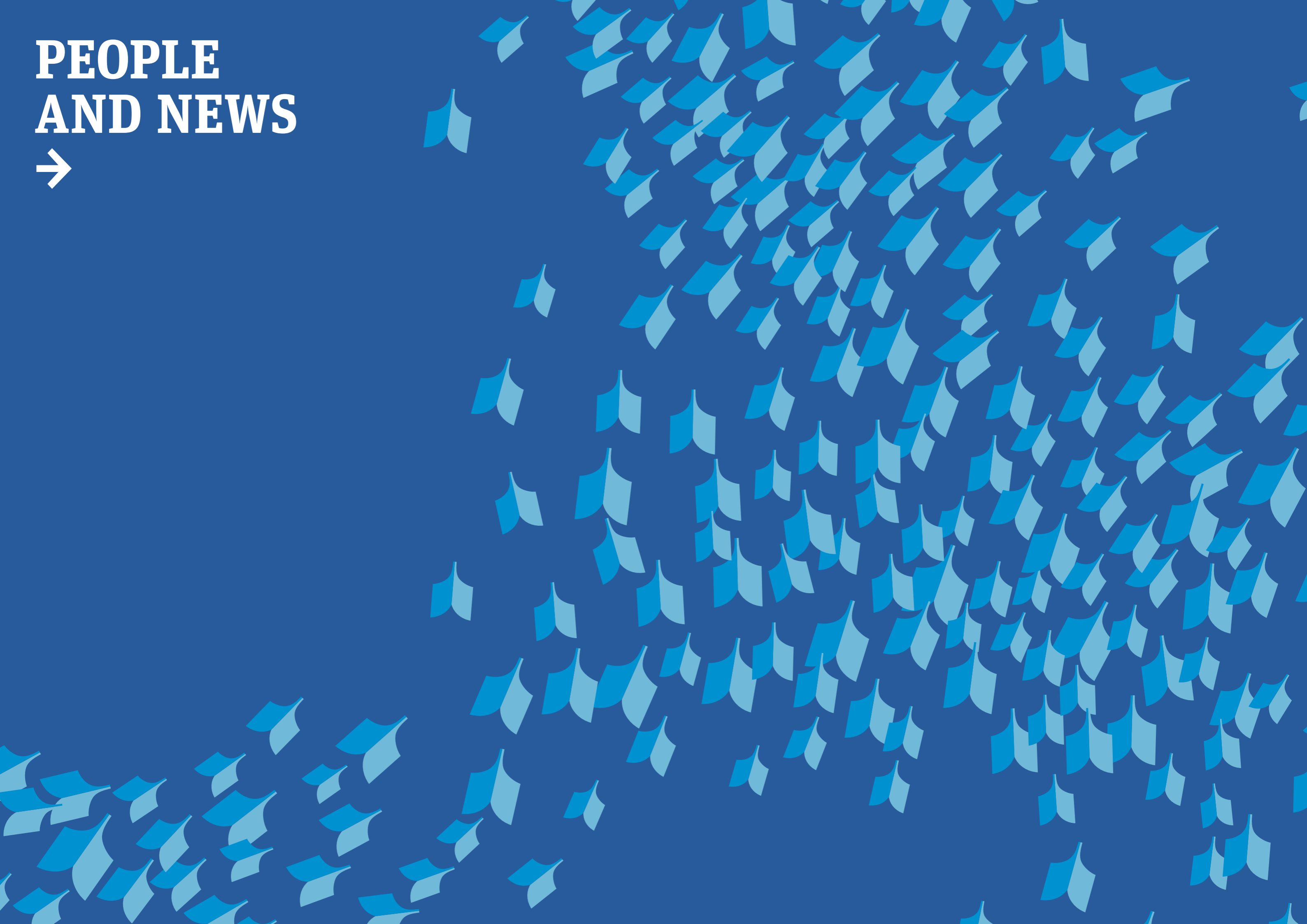
campus.uni-konstanz.de

Was Darwin heute entdecken würde

What would Darwin discover today? Eduardo Sampaio was invited to go on board the sailing ship 'Captain Darwin' and studied octopuses off Cape Verde.

seemoz.de

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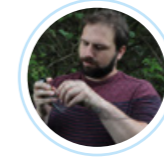
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Helge Giese

Alison Govaerts

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Mariam Mahmoud

Mahsa Mozafary

Felix Oberhauser

David Rozen-Rechels

Moritz Schlötter

Krizler Tanalgo

Camille Toscani

The CASCB mourns the death of Marcus Groettrup

The members of the CASCB mourn the death of Marcus Groettrup, who passed away after a serious illness on 2 June 2022, just a few weeks after his 58th birthday.

Marcus Groettrup had been professor of immunology at the University of Konstanz since 2002. His research aimed to promote a detailed understanding of the immune system and the underlying molecular mechanisms for the various functions of different immune cells – in both healthy and diseased cases. His pioneering research made valuable contributions to the understanding of immune responses to therapeutic approaches to fighting disease, e.g. for developing an immunotherapy to treat cancer.

Marcus Groettrup was always a highly active and collaborative member of the CASCB community. He played a leading role in one of our major research foci. He will also be sorely missed by the cluster community. The CASCB offers its sincerest condolences to his family.

PhD students

Customized workshops

Onboarding of doctoral candidates
→ Welcome letter
→ Welcome Day for newcomers
→ Buddy system
→ Introduction of new members in a newsletter
→ Wiki/knowledge base

Informative and interactive doctoral Jour fixe
→ Inviting PIs
→ Visiting labs

Retreat
Plenary session with doctoral researchers and PIs moderated by speakers & with break-out discussion groups.

Our vision for the cluster
→ Stimulate interdisciplinary collaborations
→ Increase awareness about ongoing projects
→ Formats to share ideas, connect, and cooperate
→ Welcoming and supportive social environment

Foster interdisciplinary exchange
→ Cross-stage exchange with postdoctoral researchers and PIs
→ Informal presentation slots for doctoral researchers in seminar schedule
→ Mandatory meetings of doctoral researchers
→ Lunches
→ Joint activities, such as sports

42 doctoral candidates benefit from the exchange with other young researchers on collective behaviour. To make the most of the collaboration and the time spent completing their doctoral degrees, the doctoral candidates meet regularly to develop and exchange ideas.

Awards and grants

Iain Couzin
Gottfried Wilhelm Leibniz Prize; Falling Walls Global Call Winner; Highly Cited Researcher; Rothschild Distinguished Visiting Fellowship 2023, Isaac Newton Institute, University of Cambridge

Zoe Goldsborough
3rd prize for Best Student Talk at the joint EFP-GfP 2022 Conference, Arnhem: Presentation "Tool Use and Tidal Cycles: Activity Patterns in Island-living White-faced Capuchin Monkeys *(Cebus capucinus imitator)*"

Yannick Günzel
Neurobiology Doctoral Students Workshop's Best Talk Award: Presentation "Hopper by name, hopper by nature. The state-dependent startle response of the desert locust"

Daniel Keim
Security Innovation Awards, Directorate-General for Migration and Home Affairs

Gisela Kopp
Board of Die Junge Akademie; Member of the Ukraine Support Team of the University of Konstanz who received the University Council Award 2022

Britta Renner
Vice-President of the German Nutrition Society

Katja Slangewal
Neurobiology Doctoral Students Workshop's Best Poster Award

DOCTORAL DEFENCES

Michael Chimento
17 October 2022

Eren Cakmak
6 December 2022

Lucy Aplin
European Research Council Starting Grant 2021 (SERI-funded); "CULTURES ADAPT − Animal culture under change: a landscape-level analysis of socio-cognitive responses to human impact", €1.5m

Armin Bahl
European Research Council Starting Grant 2022; "Neural basis of zebrafish collective decision-making", €1.5m

Armin Bahl
Florian Engert, Jeff Lichtman, and Marc Fishman (Harvard University): NIH U19 Collaboration Grant; "The heart and the mind: an integrative approach to brain-body interactions in the zebrafish", $288,750

Armin Bahl
and Robert Hindges (King's College London): Biotechnology and Biological Sciences Research Council International Partnerships grant; "A close-loop visual stimulation system to study neural circuits underlying animal behaviour", £44,448.46

Thejasvi Beleyur
Walter Benjamin Programme, German Research Foundation

Blair Costelloe, Andrea Flack, and Martin Wikelski
Marie Skłodowska-Curie Innovative Training Network grant: "WildDrone, Autonomous Drones for Nature Conservation Missions"

Meg Crofoot
ERC Consolidator Grant: "CO-SLEEP: The Collective Dynamics of Sleep", €2.9m

Iain Couzin and Serena Ding
EIC Horizon 2020: "BABOTS: The design and control of small swarming biological animal robots"

George Fejer
ELES Doctoral Scholarship

Urs Fischbacher
Allais Memorial Prize in Behavioural Sciences

Jeanine Grütter
Jacobs Foundation Research Fellowship, 3 years

Daniel Keim and Data Analysis and Visualization WG

→ Grant from the Federal Ministry of Education and Research, Research for Civil Security: "Verbundprojekt: Vertrauenswürdige Künstliche Intelligenz für polizeiliche Anwendungen (VIKING)"; Subproject "Visual Analytics für vertrauenswürdige und erklärbare Künstliche Intelligenz", 3 years, €492,786

→ Committee on Research (AFF), University of Konstanz; Funding lines in the framework of the Excellence Strategy: "ProPell Promoting Exercise in Lab and Life"; 32 months, €27.270,60

→ Grant from the Federal Ministry for Economic Affairs and Climate Action: "RESUME – Multikriterielle Optimierung: Auswirkungen von Recyclingpotentialen, kritischen Rohstoffen und Lieferkettenrisiken auf die Energiewende", Subproject "Visuelle Analytik für verbesserte Entscheidungsfindung"; 3 years; €325,450

→ Project grant from the Ministry of Social Affairs, Health and Integration of the State of Baden-Württemberg: "Verwendung von digitalen Fernüberwachungs- und Behandlungslösungen als wichtiger Baustein bei der Bekämpfung der COVID-19-Pandemie in Baden-Württemberg", 10 months, €162,500

Mark van Kleunen
German Research Foundation grant; "Advancing the understanding of global plant invasions: building the bridge from data to drivers and biodiversity changes ", 3 years

Liang Li
Mobility Grant, Sino-German Centre for Research Promotion: "The emergence of cooperation in schooling fish: an evolutionary game theory perspective"

Diego Morales
Herz Fellowship, Zukunftskolleg, University of Konstanz

Hemal Naik
Residency at Schloss Solitude; Project at the art/science interface related to the CASCB/MPI-AB blackbuck project

Harald Reiterer and Falk Schreiber
Gold at the CommAwards; Golden ADC Nail; Red Dot at the Red Dot Design Award for the exhibition "Stayin' Alive"

Zoe Ringleb
Anne Kern-Godal Memorial Fund: "Systematic Investigation into Stress Reducing Effects of Horse-Assisted Therapy in Acute and Chronic Stress Measured by Heart Rate Variability and Cortisol"

Katja Slangewal
Boehringer Ingelheim Fonds PhD Fellowship

Anna Stöckl
Research Fellowship, Zukunftskolleg, University of Konstanz, 5 years
Emmy Noether grant: "The neural basis of insect pattern vision"

Wataru Toyokawa
William K. and Katherine W. Estes Fund, Association for Psychological Science and the Psychonomic Society; "Computational Summer School on Modelling Social and Collective Behaviour (COSMOS) Konstanz 2022"

Katrin Vogt
Subproject leader, German Research Foundation Research Unit; "Modulation in Olfaction: How Recurrent Circuits Govern State-Dependent Behaviour"

Sonja Wild
Postdoc.Mobility Fellowship, Swiss National Science Foundation; "The impact of human disturbance on animal culture", 2 years
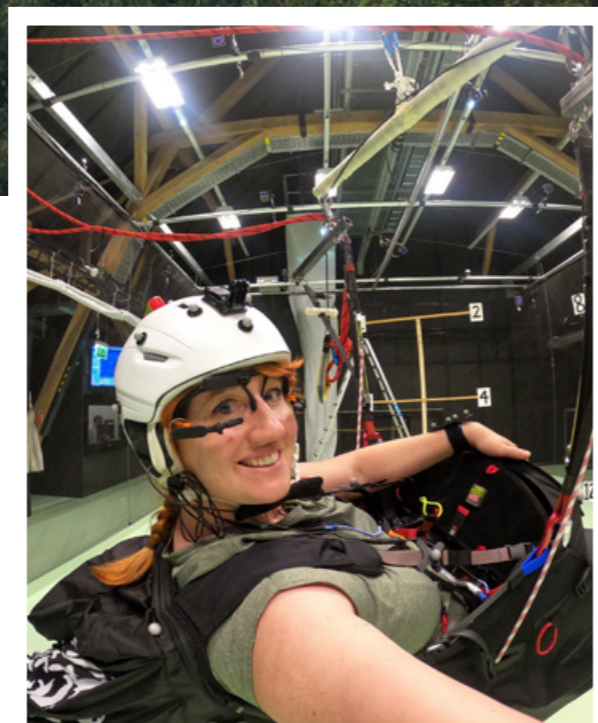
Hannah Williams
Freigeist Fellowship, Volkswagen Foundation: "Optimal Movement Theory: Perception of energies to "up-the-odds" for efficient movement", approx. €1.6m

Yuqi Zou
Herz Fellowship, Zukunftskolleg, University of Konstanz

Major grants and awards

Freigeist Fellowship for Hannah Williams

"Movement is a fundamental but complex phenomenon, and we are still a long way from being able to predict when and where animals decide to move and how they make these decisions," says movement ecologist Hannah Williams. To decipher the riddle, the researcher from the Max Planck Institute of Animal Behaviour has received a Freigeist Fellowship from the Volkswagen Foundation. Williams will conduct her studies at the Centre for the Advanced Study of Collective Behaviour (CASCB) at the University of Konstanz. The aim of the Freigeist initiative is to offer researchers the freedom for creative thinking, while at the same time providing security and a dedicated research team for at least five years. Her fellowship is worth €1.6 million.

Read more:

campus.uni-konstanz.de

Meg Crofoot awarded ERC Consolidator Grant

Meg Crofoot, a biologist at the University of Konstanz and member of the cluster executive board, has been awarded an ERC Consolidator Grant from the European Research Council to fund her *CO-SLEEP: The Collective Dynamics of Sleep* project for five years.

In her *CO-SLEEP* project, Meg Crofoot is developing a new perspective in studying sleep: she and her team are examining the social aspects of sleep in groups. They are combining traditional field observation methods with cutting-edge technologies for their studies on wild baboons in Kenya. Meg Crofoot aims to change the way we think about and study sleep. "Animals that live in groups do not sleep in isolation, but because most sleep research is conducted in laboratory settings, almost nothing is known about the social dynamics of sleep," Crofoot explains. Her *CO-SLEEP* project explicitly aims to bring the study of sleep behaviour into a collective context. "My goal is to understand how social environments shape – and are shaped by – the sleep patterns of their members. To achieve this, we have to take sleep research out of the lab and into the field," says Meg Crofoot.

Read more about the CO-SLEEP project:

www.ab.mpg.de

uni-konstanz.de

Iain Couzin – Gottfried Wilhelm Leibniz Prize, Falling Walls Global Call Winner, and Highly Cited Researcher

On 12 May 2022, Iain Couzin was honoured with Germany's most important research prize, the Gottfried Wilhelm Leibniz Prize of the German Research Foundation. Iain Couzin was applauded for his "outstanding work in the field of behavioural biology that has led to a fundamentally new understanding of collective behaviour." On this occasion, campus.kn spoke to the laureate about his research.

Iain Couzin also received a Falling Walls 2022 award in the category "Life Sciences." The prize is awarded to researchers who have submitted "groundbreaking projects." "Which are the next walls to fall in science and society?" That is the leading question of the Falling Walls Award. The jury reviewed more than 1,000 entries from 105 countries and decided that Iain Couzin is a ground-breaking researcher. In addition, he has been honoured as a Highly Cited Researcher for the fifth time in a row. Read the interview: "Five questions about the number five" with the renowned collective behaviour researcher on campus.kn.

Gottfried Wilhelm Leibniz Prize:	**A portrait by German Research Foundation**	**Falling Walls Global Call:**	**Highly Cited Researcher:**
campus.uni-konstanz.de	youtube.com	exc.uni-konstanz.de	campus.uni-konstanz.de

Katrin Vogt – Successful subproject leader of a new Research Unit of the German Research Foundation

The German Research Foundation is funding the Research Unit "Modulation in Olfaction: How Recurrent Circuits Govern State-Dependent Behaviour." Neurobiologist Katrin Vogt from the Centre for the Advanced Study of Collective Behaviour is involved as a subproject leader.

Read more:

exc.uni-konstanz.de

Anna Stöckl, leader of an Emmy Noether Independent Junior Research Group, joined the CASCB in June 2022

Why did you decide to come to Konstanz and join the CASCB?

I first got in contact with Konstanz through former CASCB member Myles Menz, who was interested in attaching radio tags to our hummingbird hawkmoths. Although the tags were a bit too heavy for the little moths to take off with, it got me very interested in the amazing new methods and facilities for animal tracking concentrated in Konstanz, which I became fully aware of through project discussions with Iain Couzin's group. Combined with the fantastic expertise in neurobiology at the university, this made it the perfect environment to start my new research group.

What is your research aim – (especially in the field of collective behaviour)?

At the core of all my research is the question of how animals use their senses to inform their behaviour. We study this on multiple levels in insect pollinators — having moths fly through tunnels and feed from robotic flowers, recording and mapping neurons in their brains, and using special cameras to see the world from an insect's point of view. Our work has very much focused on individual animals, so my move to Konstanz, and the association with the CASCB, opens up a whole new world of exciting perspectives.

**Why are you excited about starting work in collective behaviour?**

I am eager to understand how groups of pollinating insects interact with one another when foraging in the same environment: What information can they gain from each other, and how do they act collectively? I am particularly interested in whether and how solitary insects, like hawkmoths, which share their habitats and resources with many other solitary and social insects, benefit from collective interactions. Having worked to gain a good understanding of the visual ecology of insect pollinators, and the link between senses, neurons, and behaviour, I am excited to now have the tools to examine the interplay of these factors across individuals — the context in which these systems originally evolved.

ERC Starting Grant for Armin Bahl

Armin Bahl, professor of neurobiology and zoology at the University of Konstanz, has been awarded an ERC Starting Grant for his project *Neural basis of zebrafish collective decision-making*. The project has been allocated funds of €1.5m. Armin Bahl is a group leader at the CASCB and a Research Fellow at the Zukunftskolleg.

Armin Bahl plans to establish the juvenile zebrafish as a model system, as he believes it is optimally suited for studying collective decision-making. "At this intermediate developmental stage, zebrafish offer an excellent compromise between cognitive ability and experimental accessibility. They can temporally and spatially integrate information, they interact socially, and you can characterize and manipulate brain activity in intact animals," he says.

With the help of virtual reality experiments, Bahl and his team will initially dissect the algorithmic rules by which juvenile zebrafish make decisions when swimming in heterogeneous groups. Then he intends to characterize the brain activity related to this behaviour.
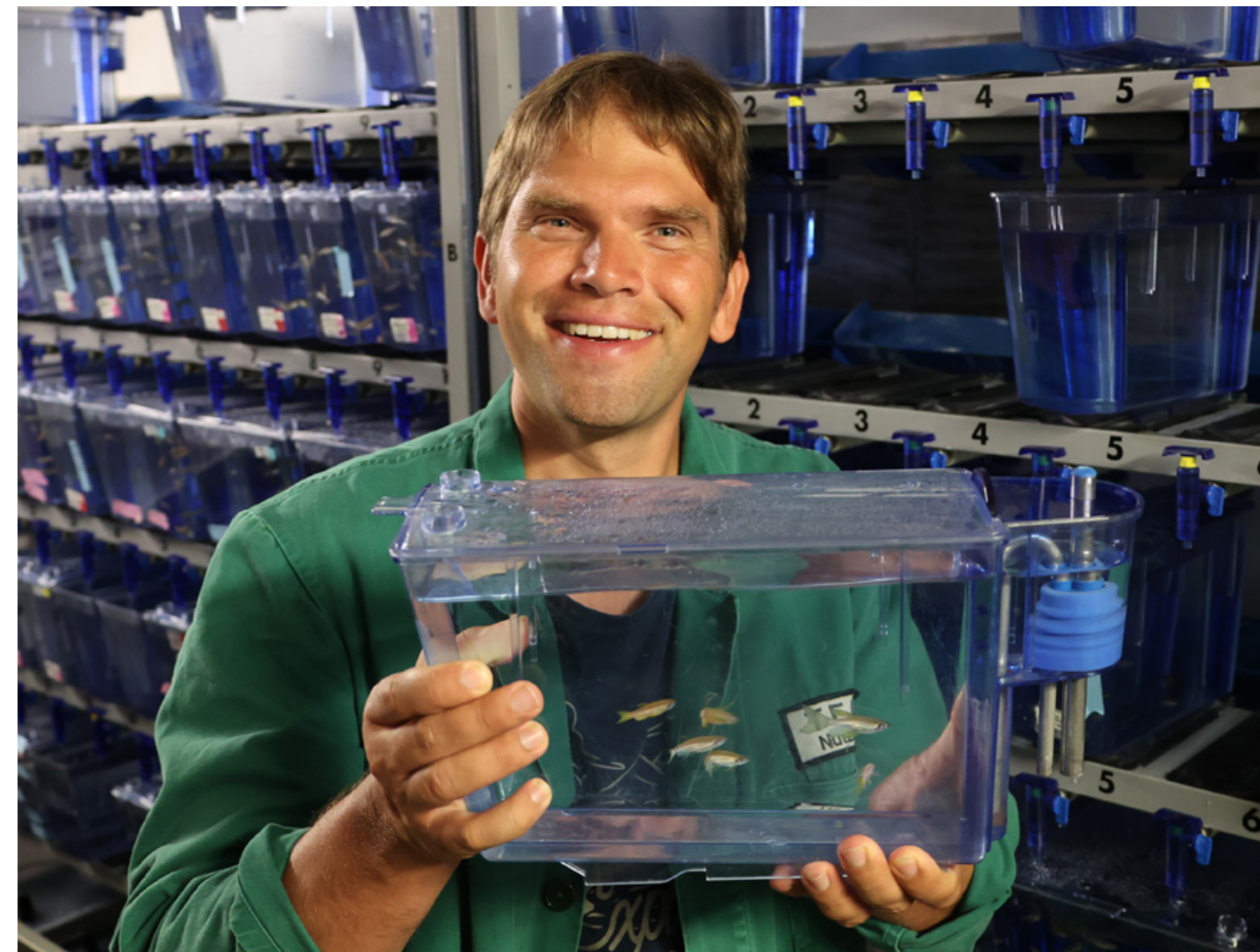
Funded projects

Title	Applicants
Ecological and social triggers of human (predator) and animal (prey) movement	Barbara Fruth
ISMiR: the influence of interoceptive signalling on self-other perception, sensorimotor and physiological synchrony, and behaviour in social interactions within mixed reality spaces	Bigna Lenggenhager, Tiare Feuchtner
Understanding and facilitating positive group dynamics in education	Jeanine Grütter
Following an indecisive leader – developing a virtual reality system to investigate how animals resolve incomplete social compass cues	James Foster
Quantitative imaging and modelling of signalling and mechanics to understand collective cell migration during zebrafish development	Patrick Müller
Collective behaviour and decision-making in wild African lions	Genevieve Finerty, Natalia Borrego
Tracking wild orangutans: understanding the when, where, and how of fission-fusion sociality in a great ape species	Caroline Schuppli, Alison M. Ahbury, Shauhin E Alavi
Foundations of imitation learning	Tobias Sutter
Individual heterogeneity to collective behaviour in nematodes	Serena Ding

Title	Applicants
Responding to physical and social cues leads soaring birds toward optimal migration routes	Elham Nourani

Title	Applicants
Establishing fecalFACS as a method for investigating the genomic relatedness networks that underlie social interaction networks in natural animal populations – Extension	Gisela Kopp
Consumables: materials to build a system to track animal social interaction	Fumihiro Kano
Student assistant to small programmes to track animal social interaction	Fumihiro Kano
Visiting speaker proposal: Dr Laura Nenzi	Tatjana Petrov
International visitor proposal: Francesca Cairoli	Tatjana Petrov
Visiting lecture series	Tatjana Petrov
International Symposium on Integrative Bioinformatics 2022	Falk Schreiber
Documentary Palaces	Blair Costelloe, Hemal Naik, Mario Doulis, Jörg Frohnmayer, Joost Bootema
Bio-inspired swarm robots	Liang Li, Oliver Deussen, Iain D. Couzin
Optimizing device and sensor programmes for monitoring collective behaviour in wild lions	Natalia Borrego, Genevieve Finerty, Richard Gunner
Optimizing device and sensor programmes for monitoring collective behaviour in wild lions	Genevieve Finerty, Natalia Borrego, Richard Gunner
Computational Summer school on Modelling Social and collective behaviour (CoSMOS)	Wataru Toyokawa, Charley Wu

SMALL GRANTS

Title	Applicants
Exploring the effect of early experience on individual vocal flexibility and group functioning	Gabriella Gall, Joah Madden
Social interactions of female and male Montagu's harrier in Spain	C. Giovanni Galizia
Collective decision-making under spatial constraints	Lior Lebovich
Drone-based observations of wild Indian wolves: a first step towards understanding collective processes in social carnivores	Adwait Deshpande
Low-latency field and laboratory analyses of primate feeding competition in a remote Central African tropical forest	Edward McLester
The sensory ecology of collective behaviour	Ari Strandburg-Peshkin
Individual and collective Red Colobus (Piliocolobus tephrosceles) movement patterns in relation to food preferences and food resources	Urs Kalbitzer
3D posture reconstruction of bird flocks	Alex Chan
Seminar: Neurocomputational approach. Nutrient-based food choices in rhesus monkeys	Hemal Naik
Social and vocal complexity in monk parakeets (Myiopsitta monachus)	Simeon Smeele
Student assistant to help develop small programmes in the animal social interaction tracking projects	Fumihiro Kano

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LEGAL NOTICE

At the Centre for the Advanced Study of Collective Behaviour, we aim to create a global hotspot for the integrated study of collective behaviour across a wide range of species and across scales of organization. We are a Cluster of Excellence within the framework of the Excellence Strategy of the federal and state governments. As a collaboration between the University of Konstanz and the co-located Max Planck Institute of Animal Behavior, we harness substantial expertise in the local region to create a synergistic, interdisciplinary environment for the study of collective behaviour that will be unmatched by any institution around the world. Combining transdisciplinary research with emerging technologies, we are creating a crucible in which the ideas and methods of tomorrow will be forged. Whether you are a researcher, business, or member of the public, we invite you to discover the people and ideas in this hub for collective behaviour.

uni-konstanz.de/collective-behaviour