THE ASSOCIATION FOR THE STUDY OF ANIMAL BEHAVIOUR

ASAB

KONSTANZ
SUMMER
CONFERENCE

2019

Centre for the Advanced Study
of Collective Behaviour

WELCOME

Welcome all to Konstanz for the ASAB Summer 2019 Conference "New Frontiers in the Study of Animal Behaviour"! It is an extremely important time to be studying animal behavior. Impacting biological processes across vast scales, from the neural, genetic and endocrine interactions within organisms, to the interactions among organisms, and the emergent functional complexity of groups, populations and ecosystems, behavior is a crucial component of almost all ecological and evolutionary processes.

With ongoing dramatic innovations in technologies, such as computer vision, global positioning systems, genetic manipulation, physiological recording, machine learning and the ability to immerse organisms into synthetic worlds, we are poised to transform the study of animal behavior and to develop approaches that do not ignore the complexities and dynamical relationships in the natural world, but rather embrace them. In addition to providing new fundamental biological and bio-medical insights, the integrative and quantitative study of behavior will increasingly be essential for the development of evidence-based policies and strategies in to conserve biodiversity in the face of unprecedented anthropogenic disturbance.

The Centre for the Advanced Study of Collective Behaviour at the University of Konstanz and the newly founded Max Planck Institute of Animal Behavior in Konstanz and Radolfzell are delighted and honored to have the opportunity to invite you all to beautiful Lake Constance at such an exciting time. We very much look forward to a dynamic, fun and productive meeting!

Iain D. Couzin

INSTRUCTIONS

INSTRUCTIONS TO TALK PRESENTERS

Regular oral presentations will be 10 min long with 3 additional minutes for discussions and then 2 minutes for changing rooms. All rooms will have both Mac and PC connected to the presentation system with a current version of Powerpoint and Keynote. You will not be able to connect your own device for a contributed talk. It is highly recommended that presenters bring their talk on a USB as backup to their presentation. Don't forget to embed media or have it in a folder with your presentation. Presentations should be formatted for 16:9 aspect ratio and labelled as:
LASTNAME-ASAB-2019

Presentations must be uploaded at least 4 hours before your talk. Upload and testing can take place at the following times:

Monday, 26 August 8:00-18:00 (in A703) and 13:00-17:00 (in the Audimax)
Tuesday, 27 August at 7:30-8:30 and 12:30-13:10 and 16:40-18:40 in your allocated presentation room
Wednesday, 27 August at 7:30-8:30 and 12:50-14:00 in your allocated presentation room

INSTRUCTIONS TO POSTER PRESENTERS

All posters will be displayed in the foyer of the main "A" building. Assigned poster numbers are in the Index available online. Mounting materials and no Twitter signs will be provided onsite. Presenters should stand by their poster at the session on Tuesday 27 August, according to their number: evens from 16:40-17:25, and odds from 17:25-18:15.

REGISTRATION

The conference starts on Monday 26 August at the University of Konstanz with registration from 8am. The registration desk is in the main "A" building and there will be plenty of signs to direct you from the entrance. Transportation to the university is detailed below. The desk will be open all day Monday (until 18:00) and every morning (8-9am) on Tuesday and Wednesday. Last minute registration is possible via cash.

PROGRAM

You can currently access an Overview Schedule and Talk Schedule (subject to change) as well as Talk Abstracts, Poster Abstracts and Index of Presenters at uni-konstanz.de/asab-summer-2019/schedule

WIFI

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LIVE STREAMING

In order to encourage open science, the presentations of plenary sessions who have given their permission will be recorded and broadcast by live stream at uni-konstanz.de/asab-summer-2019

STAFF & VOLUNTEERS

Besides registration and info desk staff, there are conference volunteers who can be identified by blue “STAFF” badges at the venue. Feel free to ask them for any assistance you may need.

BUS PASS

Delegates will receive complimentary bus passes from the City of Konstanz (tickets provided at registration). Tickets allows you to use any local bus services in Konstanz without limit from Monday 26th until Wednesday 28 August.

LUNCHES AND COFFEE

A buffet lunch is included on Tuesday 27 and Wednesday 28 as a part of the conference registration fee. Lunch is served in the “Mensa” cafeteria and seating is in a reserved space “K7” or anywhere in the cafeteria. Coffee/tea and snacks are also served during breaks (see schedule).

SOCIAL EVENTS

Welcome Reception: Monday, 26 August

Following the official opening plenary, a welcome reception will be held in an event space in the main "A" building. Complimentary finger food and drinks will be served until 21:00, after which the party will continue informally in beautiful Konstanz town.

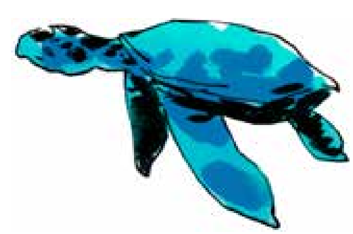
Mainau: Tuesday, 27 August

We are hosting an excursion to the Mainau “flower” Island on day two of the conference. Entry is free of charge but requires showing your name badge to the reception desk. We will be walking together from the university (20 minutes) so please let an orgainser know if you require special assistance. Also, pack wet weather gear to ensure that you don’t miss out on experiencing this top attraction. Please note that restaurants are available on the island and are at one’s own expense.

Conference Dinner: Wednesday, 28 August

Last but by no means the least, the official conclusion of ASAB Summer 2019 will be a banquet dinner held in arguably the most important building in Konstanz: the “Konzil”. Dating back to the 1400s, the structure was the site of the Council of Konstanz (1414-1418), a convening for the election of a pope that became the largest congress of the Middle Ages .

600 years later, the venue remains an ideal convention address. A pre-dinner drink will be served from 18:30 on the Konzil’s generous terrace overlooking Lake Constance (one complimentary sparkling wine or soft drink and further drinks available for purchase). Dinner starts at 19:30 and includes a buffet with complimentary drinks until 23:00 (further drinks can be purchased from the bar). The ASAB Medal will be presented during the dinner and a DJ will take over from 22:00 to 01:00 when the event concludes. Tickets are pre-purchased and your name badge must be presented to enter. Dinner tickets can be purchased at the registration desk.



ACKNOWLEDGMENTS

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ASAB Summer 2019 Overview Schedule

26 – 28 August, University of Konstanz, Germany

Monday, 26 August

08:00 – 09:00	Registration and welcome coffee/tea
09:00 – 12:00	**Workshop: Machine learning in the behavioural sciences**
12:00 – 13:00	Lunch
13:00	**Workshop: Quantifying behavior with machine-learning** 13:00 – 17:00 **Workshop: Low-cost automation of behavioral experiments with rasp-berry pi's** 13:00 – 16:00 **Workshop: Recording and analyzing acoustic data** 13:00 – 17:00
17:00 – 18:00	Coffee and tea break
18:00 – 18.50	**Welcome & Opening Plenary Lecture** Nachum Ulanovsky: "Neural codes for natural behaviors in flying bats"
18:50 – 21:00	Welcome Reception

08:00 – 18:00 Registration & Talk Upload

Tuesday, 27 August

08:00 – 08:50	Registration and coffee/tea
08:50 – 09:00	Morning Update
09:00 – 09:40	**Plenary Lecture 2** Dora Biro: "Collective action at the cognition-culture interface"
09:40 – 10:00	Coffee and tea break
10:00 – 11:15	**Session 1**
11:15 – 11:45	Coffee and tea break
11:45 – 12:25	**Plenary Lecture 3** Jason Kerr: "Imaging brain and behaviour in freely moving mammals" Introduction by: Iain Couzin
12:25 – 13:40	Lunch
13:40 – 14:55	**Session 2**
14:55 – 15:25	Coffee and tea break
15:25 – 16:40	**Session 3**
16:40 – 18:15	**Poster Session**
from 18:15	Guided groups depart to Mainau flower island

Wednesday, 28 August

08:00 – 08:50	Registration and coffee/tea
08:50 – 09:00	Morning Update
09:00 – 09:40	**Plenary Lecture 4** Mary Stoddard: "Bird's-eye View: How Colour, Court-ship and Deception Shape the Avian Visual World"
9:40 – 10:00	Coffee and tea break
10:00 – 11:00	**Session 4**
11:00 – 11:30	Coffee and tea break
11.30 – 12:45	**Session 5**
12:45 – 14:20	Lunch
13:20 – 14:20	**ASAB AGM**
14:20 – 15:00	**Plenary Lecture 5** Meg Crofoot: "Science of the Sociome: Tracking how interactions scale to complex societies"
15:00 – 15:20	Coffee and tea break
15:20 – 16:20	**Session 6**
16:20 – 16:40	Coffee and tea break
16:40 – 17:40	**Session 7**
17:40 – 18:00	**Prize Presentation and Closing Words**
18:00 – 18:30	Free
18:30 – 19:30	Apéro at Konzil (dinner ticket)
19:30 – 01:00	**Conference dinner and ASAB medal presentation**

Workshops · Plenaries · Sessions

– uni.kn/asab-summer-2019

Oral presentation abstracts

1

Social dynamics in a basal primate with facultative sociality

Lluis Socias-Martínez[1,2], Peter M. Kappeler[1,2]

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The origins of sociality remain widely debated in both vertebrates and invertebrates. Among suggestions for advancing our understanding in this matter, the study of facultatively social species is key. We investigate social dynamics in a wild population of a facultatively social primate species, the grey mouse lemur (*Microcebus murinus*). In this nocturnal solitary forager, nest sharing corresponds with communal breeding, allocare and predator mobbing. We monitored sleeping associations of 250 individuals for two consecutive years in 120 nests. Preliminary analyses indicate the presence of at least three different social strategies in both males and females. Some individuals were never observed sleeping in the company of others, a second type appears to show stability in associations and a low number of partners, while a third type shows high connectivity with other third type individuals. In further analyses, we implement social network metrics to explore associations dynamics for that subset of the population showing high connectivity and flexibility in partner choice. Our study may offer a glimpse into the characteristics of initial stages of primate sociality and contribute to unravelling the mechanisms and ecological contexts that contributed to its spread and maintenance.

Parallel evolution of termite tunneling with differentiated behavioral rules

Nobuaki Mizumoto[1], Paul M. Bardunias[2], Stephen C. Pratt[1]

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[2]SUNY College of Environmental Science and Forestry, United States

Collective behaviors by grouping animals form various spatial patterns, including coordinated motion and nest structures. These patterns often vary within or among species, where a key question is how different group-level patterns emerge from individual responses and their interactions. In termites, tunneling through the soil by collective excavation has evolved several times; however little is known about the behavioral mechanisms underlying the pattern formation. Here we show convergent evolution of tunneling behaviors in termites accompanied by differentiation of behavioral rules for collective excavation. We found novel digging behavior in *Paraneotermes simplicicornis* (*Kalotermitidae*), who use their legs to kick back sand particles, contrasting with well-known behavior of *Reticulitermes tibialis* or *Heterotermes aureus* (*Rhinotermitidae*) who carry sand with their jaws. In spite of this variation, *P. simplicicornis* and *R. tibialis* showed less branching of tunnels, while *H. aureus* built more branched tunnels. We attribute this to the higher frequency of behavior by *H. aureus* in which they excavate side walls inside clogged tunnels, which we confirmed by data-based simulations. These results suggest that different behavioral repertoires can produce similar tunneling structures, where small modification of the behavioral parameter is important to determine the patterns. Based on these data and ongoing studies of basal species, we discuss the evolutionary process of termite collective building.

3

Phenotypic behavioural variation at different hierarchical levels during rapid adaptation from fluctuating to stable environments

Žiga Fišer[1], Simona Kralj-Fišer[2,3], Gergely, Balázs[4], Gergely Horváth[4], Cene Fišer[1*], Gábor Herzeg[4*]

[1]Department of Biology, Biotechnical Faculty, University of Ljubljana, Slovenia,
[2]Institute of Biology, Research Centre of the Slovenian Academy of Sciences and Arts, Slovenia,
[3]Faculty of Mathematics, Natural Sciences and Information Technologies, University of Primorska, Slovenia,
[4]Behavioural Ecology Group, Department of Systematic Zoology and Ecology, Eötvös Loránd University, Hungary,
*co-senior author

Understanding phenotypic variation in the wild has been a central topic of biology since Darwin recognized it as a fundamental prerequisite for evolution by natural selection. However, explaining mechanisms responsible for within-population maintenance of phenotypic variation in fitness-related traits is still a major challenge. Much of previous work examined whether temporally and spatially fluctuating selection arising from heterogeneous environments increases phenotypic variation. The complementary perspective postulating that stabilizing selection decreases phenotypic variation when organisms adapt to homogeneous environments has received surprisingly little attention. We propose cave and surface environments as an ideal comparative model system to test this hypothesis, as variation of most environmental factors is strongly diminished in caves compared to the surface. Additionally, labile quantitative behaviours seem promising traits to investigate the evolution of phenotypic variation as they can be inspected across different hierarchical levels including the within-individual level. We applied this logic and repeatedly measured individual's behaviour in familiar (6x) and unfamiliar (2x) environments in four cave-surface population pairs representing independent cave colonisations of the freshwater crustacean *Asellus aquaticus*, an emerging model organism for rapid evolutionary adaptation. To control for sex and light regime induced variation, we collected 30 males and females per population and randomly assigned them into two groups that were alternatingly acclimatized to darkness and diurnal light cycle prior video-recording their behaviour in the same light conditions. Preliminary analyses suggest changes at different levels of phenotypic behavioural variation associated with cave adaptation. We expect our study will provide novel insights on an old question.

4

Bet-hedging across generations can affect the evolution of variance-sensitive strategies within generations

Thomas Ray Haaland[1,2], Jonathan Wright[1], Irja Ida Ratikainen[1]

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In order to understand how organisms cope with ongoing changes in environmental variability it is important to consider all types of adaptations to environmental uncertainty on different time-scales. Conservative bet-hedging represents a long-term genotype-level strategy that maximizes lineage geometric mean fitness in stochastic environments by decreasing individual fitness variance, despite also lowering arithmetic mean fitness. Meanwhile, variance-prone (aka risk-prone) strategies produce greater variance in short-term payoffs because this increases expected arithmetic mean fitness if the relationship between payoffs and fitness is accelerating. Using two evolutionary simulation models, we investigate whether selection for such variance-prone strategies are counteracted by selection for bet-hedging that works to adaptively reduce fitness variance. We predict that variance-prone strategies will be favored in scenarios with more decision events per lifetime and when fitness accumulates additively rather than multiplicatively. In our model variance-proneness evolved in fine-grained environments (with lower correlations among individuals in energetic state and/or in payoffs when choosing the variable decision), and with larger numbers of independent decision events over which resources accumulate prior to selection. In contrast, geometric fitness accumulation caused by coarser environmental grain and fewer decision events prior to selection favors conservative bet-hedging via greater variance-aversion. We discuss examples of variance-sensitive strategies in optimal foraging, migration, life histories and cooperative breeding in light of these results concerning bet-hedging. By linking disparate fields of research studying adaptations to variable environments we should be more able to understand the effects in nature of human-induced rapid environmental change.

5

The role of the epigenome in plastic responses to rapidly changing social environments

James Rouse[1], Thomas Leech[2], Elizabeth Duncan[1], Amanda Bretman[1]

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[2] Department Partridge, Max Planck Institute for Biology of Ageing, Germany

Social environments can be very dynamic and have important consequences for fitness. For example, males use social information to predict the amount of mating competition they will face and adjust investment in particular mating opportunities accordingly. To accurately match their reproductive strategy to this fluctuating environment requires plasticity that is fast acting and reversible. Whilst the role of the epigenome in responses to environmental change is becoming more understood, it has been suggested that it is not invoked in such flexible plasticity. We sought to test this using a *Drosophila melanogaster* fruit fly model. Male flies adjust their mating duration and ejaculate composition depending on the level of sperm competition signalled by exposure to rival males before mating. The behavioural component of this change occurs quickly (under 24h) and is entirely reversible. A previous transcriptome study showed that the expression of some epigenetic modifiers is sensitive to exposure to rival males. Here, we used chemical inhibitors and RNAi to test whether epigenetic remodelling is required to achieve this plastic response. We found histone deacetylation is crucial to a male's ability to plastically respond to increased sperm competition, but in a tissue specific manner. We are now investigating which loci are targeted by epigenetic remodelling in response to plasticity using ChIP-seq. Overall, this suggests epigenetic remodelling is an important mechanism in short-term, reversible plastic phenotypes, and must be considered when exploring adaptations to fluctuating environments.

6

Is there reciprocal cooperation in non-human primates?

Manon K. Schweinfurth[1], Josep Call[1]

[1]School of Psychology Neuroscience, University of St Andrews, UK

Reciprocal cooperation, i.e. helping those that were helpful before, is a ubiquitous and important trait of human sociality. Still, the evolutionary origin of this behaviour is largely unclear, mainly because it is believed that our closest living relatives, other primates, do not exchange help reciprocally. Consequently, reciprocity is suggested to have evolved in the human lineage only. However, recent findings challenge this view by demonstrating reciprocity in animals distantly related to us, such as rats and bats. Therefore, we systematically reviewed studies investigating reciprocity in non-human primates. Contrary to common belief, there are significantly more positive than negative findings in both experimental and observational studies. A thorough analysis of the findings showed that reciprocity is, for example, not confined to unrelated individuals, but that the choice of commodities can impact the likelihood of reciprocation. We conclude that reciprocal cooperation in non-human primates is present but largely neglected and not restricted to humans. In order to deepen our understanding of the evolutionary origins of reciprocity, future studies should investigate when and how reciprocity in non-human animals emerged and how it is maintained.

7

Direct and indirect benefits as drivers of complex group structure

Joachim G. Frommen[1], Dario Josi[1], Frank Groenewoud[1,2], Jana Flury[1,3], Fabian Heussler[1], Michael Taborsky[1]

[1]University of Bern, Switzerland,
[2]University of Cambridge, United Kingdom,
[3]Forschungsmuseum A. Koenig, Bonn, Germany

Cooperative breeding, i.e. individuals helping others in their brood care, is among the most derived social behaviors. It can be explained by helpers gaining indirect fitness benefits through increasing the survival of related individuals. However, indirect fitness benefits cannot explain why unrelated individuals help others in raising offspring. Here, direct benefits are of importance. Protection from predators is such direct benefit and has been acknowledged as a major driving force of sociality. Still, how such risk related direct benefits interact with indirect fitness benefits in driving the evolution of complex cooperative societies is limited. We investigated this interplay in the cooperatively breeding cichlid *Neolamprologus pulcher*. We measured group structure, helping behavior, relatedness and reproductive success in eight populations, differing in predation risk. Group structure related to predation risk, with groups in high risk populations containing more large helpers that engage most in predator defense. In these populations the number of large helpers had a strong effect on the breeder's chance to reproduce. Microsatellite analyses revealed that the degree of within-group relatedness was generally low. Notably, smaller helpers, which invest least in defense, were more related to breeders in high risk populations. These results indicate that direct fitness benefits play a crucial role in the cooperative system of *N. pulcher*, which can be further modified by indirect fitness gains depending on the predatory environment. Our work highlights the importance to understand the interplay of direct and indirect benefits when aiming to comprehend the evolution of complex animal societies.

8

Relatedness, social structure and helping behaviour in the cooperatively breeding cichlid *Neolamprologus savoryi*

Dario Josi[1], Dik Heg[1], Tomohiro Takeyama[2], Danielle Bonfils[1], Dmitry A. Konovalov[3], Joachim G. Frommen[1], Masanori Kohda[4], Michael Taborsky[1]

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[2]Okayama University, Japan,
[3]James Cook University, Austrailia,
[4]Osaka City University, Japan

The evolutionary mechanisms underlying cooperative societies, where breeders and other individuals collaborate in raising offspring, pose an intriguing challenge. Kin selection is thought to play an important role in the development and stability of such cooperative groups, but many species exhibit a complex within-group relatedness structure, where indirect fitness benefits alone cannot explain helping behaviour. The Lake Tanganyika cichlid *Neolamprologus savoryi* has been shown to breed in cooperative harems, wherein up to four breeding females form subgroups and may be assisted by helpers. The relatedness structure of these groups is hitherto unknown, which precludes understanding of the selection mechanisms underlying apparently altruistic alloparental care. Here we present the genetic relatedness patterns of 43 groups from two populations containing 578 individuals, using 10 to 13 microsatellite DNA markers. Helpers were significantly more related to the breeding male than to the breeding female. Within subgroups, breeder to helper and helper-to-helper relatedness declined with increasing helper age. Comparison between sub-groups within a male harem revealed that helpers were more related to the breeding female they were assisting than to neighbouring females. Immigrants accounted for 16.5% of the group members, while patrilineal and matrilineal inheritance were common due to rapid breeder turnover. Interestingly, female inheritance was more likely in large than in small harems. Breeder and helper workload significantly increased with the number of young produced within the harem. Our results highlight the importance of both direct and indirect fitness benefits in a cooperative society comprising complex social and relatedness structures.

9

Isotocin receptor expression and social experiences in the Trinidadian guppy (*Poecilia reticulata*)

Sylvia Dimitriadou[1], Eduarda Santos[1], Darren P. Croft[1], Safi K. Darden[1]

[1]Centre for Research in Animal Behaviour, University of Exeter, United Kingdom,
[2]Biosciences, University of Exeter

Across taxa individuals cooperate, paying costs so others can benefit. While research has focused on the behavioural strategies underlying the emergence and maintenance of cooperation, little is known about the proximate mechanisms underpinning it. Nonapeptides, such as oxytocin, and their associated receptors are thought to be important regulators of prosocial behaviours, including cooperation. Here, we use the Trinidadian guppy (*Poecilia reticulata*), to explore the neuroregulatory response of experiencing cooperation or defection from the social environment, by examining gene expression for the isotocin receptor (itr = homologous to the mammalian oxytocin receptor). We tested females from a High Predation (HP) and a Low Predation (LP) site of the Guanapo river on the island of Trinidad in a predator inspection paradigm, manipulating whether social partners ostensibly cooperated or defected during inspection. HP fish originate from a habitat abundant in predators and are therefore experienced in predator exposure, compared to fish originating from LP habitats. The relative expression of the itr gene in brain midsection was then quantified. We found that in HP fish exposed to a predator, ostensibly experiencing defection from the social environment led to 1.5*10-1-fold higher itr midsection relative expression than experiencing cooperation. In the absence of a predator, ostensibly experiencing defection led to 1.3*10-1-fold lower itr relative expression compared to cooperation. We found no difference in itr relative expression in the inexperienced population (LP). Our findings demonstrate the effects of cooperative experiences on brain nonapeptide receptor gene expression patterns, and provide insight into the neuromodulatory mechanisms underlying cooperative behaviour.

10

Ant activity-rest rhythms vary with age and interaction frequencies of workers

Haruna Fujioka[1], Masato S. Abe[2], Yasukazu Okada[3]

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[3]Department of Biological Sciences, Tokyo Metropolitan University, Japan

Social insect colonies are highly organized systems, where communication among nestmates (i.e. social interactions) has a pivotal function for colonial organization. In order to further the understanding of social organization, the chronobiological system of social insect species, particularly their circadian rhythm, has recently attracted much attention. However, gaps still remain in our understanding of how individual active/rest rhythms are governed in various social contexts. In this study, we investigate the effects of worker-worker interactions on circadian activity rhythms, using the monomorphic ant, *Diacamma sp*.

Continuous tracking of solitary ants elucidated circadian activity rhythms, both in young and old workers. The color-tag based automatic tracking of multiple workers revealed that young old interactions reduced circadian rhythmic activities in both young and old workers, whereas young workers retained active/rest rhythms under young-young worker interactions. Together with the analyses of worker-worker interaction frequencies, we conclude that interactions between workers in different age-groups (i.e. workers with different tasks) function as different cues to alter worker active/rest patterns. We discuss the potential roles of worker-worker interactions on the chronobiological organization of the ant society.

11

Flapping for migrating: energy expenditure quantification

Gennaro Vitucci[1], Renaud Ronsse[1], Philippe Chatelain[1]

[1]Université catholique de Louvain

Modern high-resolution technology allows tracking migrating birds over long distances. Depending on species, duration of displacement, environmental conditions, social organization, etc., different flock topology and flight dynamics arise. Two main flying styles are typically used: soaring/gliding and flapping flight. The former's performance has been studied in details for single birds as it is achieved with fixed wings, whose modelling relies on the aeronautic tradition. Soaring/gliding is cheap, as it harvests all the energy from upwards 'thermals'. Social implications for the flock have recently been pointed out. Nevertheless, a range of circumstances makes the choice of flapping flight a preferable or unavoidable option: absence of near thermals, size of the animal, and strict time requirements, e.g. seasonal availability of food at destination. Our current work focuses on flapping flight. In particular, we intend to unveil observed flock spatio-temporal synchronization through the quantification of the mechanical power required for flying in group - and related disparity in energy consumption between leader and follower. For this purpose, we developed a novel aerodynamic model that achieves a trade-off between computational affordability for a large number of birds and essential features of collective flapping flight: 3D motion, bird-wake interaction and unsteadiness. Stable configurations, representative of formation flight, and transient ones predicting the cost of maneuver are analysed. Where available, comparison with field-data are reported. Finally, application of our cheap computational technique in light of decision-making strategies implementation are prospected. Acknowledgements: This work has received funding from the Belgian Joint Research Activity RevealFlight.

12

Individual tracking reveals consistent headings in migrating hawkmoths

Myles H. M. Menz[1,2], Martin Wikelski[1,2]

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Insects are the most diverse and abundant group of terrestrial migrants. However, in comparison to vertebrates, the migratory pathways of insects and behaviour en route are relatively poorly understood. While individual tracking can allow for insects to be monitored during migration, this technique has rarely been applied, primarily due to most insect species being too small to carry radio-transmitters. Here we present the first study to individually track nocturnal migrating insects, to identify migratory routes and understand factors affecting flight behaviour. Using a Cessna 172 aeroplane, we tracked individual hawkmoths (*Acherontia atropos*, *Sphingidae*), fitted with 0.25 g radio-transmitters. During tracking, all moths maintained a consistent heading, which persisted across days in some individuals. However, there was variation in headings among individuals. Furthermore, we analysed wind data to determine if moths compensated for wind drift in order to maintain consistent headings.

13

Closer-to-home' strategy benefits juvenile survival in a long-distance migratory bird

Yachang Cheng[1,2], Wolfgang Fiedler[1,2], Martin Wikelski[1,2,3], Andrea Flack[1,2,3]

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Human-induced changes in climate and environment are challenging the existence of migratory species. Species with diverse and flexible migratory behaviour suffer less from population decline, as they are more capable to response by altering migratory behaviour. At the individual-level, variations in migratory behaviour may lead to differences in fitness and subsequently influence demographic dynamics. Using lifetime GPS bio-logging data from 169 white storks (*Ciconia ciconia*), we answer whether their recently shortened migration has survival benefit during the juvenile stage, the riskiest life period for many migrants. We also explore how other variations in migratory decisions (i.e. time, destination), movement activity (measured by the overall body dynamic acceleration), and early life conditions influence juveniles' survival. We observed that first autumn migration was the riskiest period for juvenile white storks. Individuals that migrated shorter distances and fledged earlier experienced lower mortality risk. In addition, higher movement activity and overwintering 'closer-to-home' in Europe and North Africa (84.21% of tracked individuals adopted this new strategy) were associated with higher survival. Our study shows how quickly avian migrants can change life history decisions linked to fitness and thus helps us to understand and predict how migrants respond to the changing world.

14

Seasonal contrasts in individual consistency of oriental honey buzzards' migration

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Individual consistency, or how repeatable individuals are, in migration can help us understand the mechanisms of migration. Most studies reported that birds are more consistent in the timing than in the routes or stopover sites during migration, but some specialist species showed the opposite patterns, being more consistent in spatial than temporal aspects of migration. One possible explanation for this contrast is that specialists rely on particular food or habitat resources, which restrict the migratory routes they can take, leading to high spatial consistency. If this is the case, the effect of specialist foraging should become apparent only when birds forage, instead of fasting and flying continuously. To test this effect, we analysed individual consistency in migration of the oriental honey buzzard (*Pernis ptilorhynchus*), a specialist raptor that feeds on honeybees and wasps, using a long-term tracking data set. As honey buzzards make extended stopovers during which they forage in spring but not in autumn, the spatial consistency should be higher in spring than in autumn. Honey buzzards were highly consistent in both their migratory routes and stopover sites in Southeast Asia, but only during spring migration. While birds showed significant repeatability in timing of migration both in autumn and spring, the seasonal difference was less conspicuous compared to that in routes. Our results highlight an important link between species' migratory consistency and foraging ecology.

15

Differential use of energy available in the landscape by two soaring bird species

Martina Scacco[1,2], Andrea Flack[1,2], Olivier Duriez[3], Martin Wikelski[1,2], Kamran Safi[1,2]

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Soaring birds use the energy available in the environment in the form of atmospheric uplifts, to subsidize their flight and move across the landscape. Their movement pattern is therefore shaped by the spatial and temporal availability of uplifts, resulting from an interaction of local atmospheric conditions with the underlying landscape structure. So far, the energy available in the landscape and the cost of transport of soaring birds have been related to atmospheric information only. Here we compared the accuracy of static landscape features (topography, land cover) and commonly used uplift estimators (based on atmospheric information) in predicting the flight behaviour of two obligate soaring species, the white stork *Ciconia ciconia* and the griffon vulture *Gyps fulvus*. We used soaring and flapping flight locations of 67 individuals as indicative of the presence and absence of uplifts. We found that static landscape features alone can predict and map the uplifts available to the two species across Europe. Both species strongly rely on the availability of uplifts. However, the uplift availability maps suggested species-specific differences in the use of the landscape and the available energy. These uplift availability maps highlight the importance of considering inter-specific differences, even in species with similar flight behaviour, when generalizing the complex relationship between environment and movement patterns. These maps provide a base to explore the effects that changes in the landscape structure have on the energy expenditure for different soaring species, allow identifying low-cost movement corridors and can ultimately inform the planning of anthropogenic developments.

16

Life-long repeatability and heritability of sexual display behavior in captive-bred African houbara bustards

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Between-individual variation in behaviour (i.e. personality) has been described in a wide range of animal taxa. However, personalities have been mostly investigated along a few behavioural axes, typically involving activity, exploration, boldness and sociability, while other behavioural domains have been largely neglected. Notably, despite the documented existence of discrete alternative mating strategies across several species, typically either condition-dependent or under simple Mendelian genetic control, few studies have investigated continuous individual differences in sexual behaviour and its degree of quantitative polygenic control. We therefore assessed between-individual variation in sexual behaviour, and its underlaying genetic versus environmental components, in a captive-bred population of the North African houbara bustard (*Chlamydotis undulata undulata*), a promiscuous long-lived species, wherein males display in exploded leks to attract females. Using a large sample of more than 1 000 000 behavioural observations across more than 3 000 captive males, and spanning a period of 15 years, we found long-term individual repeatability in the extent of sexual displaying in isolation and in the occurrence of precopulatory display behaviour towards a dummy female, together with individual differences in the seasonal expression of these behaviours, and age-dependent individual trajectories, including variation in senescence patterns. We further highlight associations between behaviour, body size and condition. Among-individual variation in these traits was underlaid by significant genetic components. We discuss factors that may have generated and maintained heritable variation in sexual behaviour, and the relevance of these findings for the fields of animal personality and sexual selection.

17

Experimentally flight-impaired females show higher levels of extra-pair paternity in a passerine bird

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There is yet no consensus on the reasons why females engage in extra-pair copulations (EPC) and although in some species they may accrue indirect benefits, these effects are by no means common. The sexual conflict hypothesis posits that extra-pair paternity (EPP) is the result of strong selection for male pursuit of EPC without real benefits for females. In order to test this hypothesis, we experimentally reduced wing area (reversibly tying together some primary feathers), thereby increasing wing loading (body mass/wing area), which is negatively associated with flying ability and thus, with capacity to escape from unwanted copulations, in a group of pied flycatcher females (*Ficedula hypoleuca*). We compared EPP in their broods with those in a group of control females. Our results showed a significant increase in EPP in nests of the experimental treatment compared with control nests. These results suggest that in our study population, EPP could be partly a product of female capacity to avoid EPCs.

18

On the evolution of monandrous mating strategy in moths

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In most sexual breeding species females are polyandrous and thus most females mate more than once, whereas in the minority of species female are monandrous, whereby most females in the species mate once only. Males in both mating systems typically mate more than once. During mating, male moths transfer to females a spermatophore full with nutrients and two types of sperm, eupyrene, the fertilizing sperm that is produced in limited amounts, and apyrene, a none fertilizing sperm, that is produced in high numbers and is assumed to have a role in sperm competition. Testing the costs and benefits of remating in the monandrous moth *Lobesia botrana*, we applied strong selectin for polyandry, producing 70% of remating females, vs 90% of monandrous females in the wild type. After a few generations we measured the sperm content in testes of virgin and mated males and found that sons of polyandrous females have had an increased amount of the apyrene sperm and they transferred to females more of the apyrene sperm than sons of monandrous females. Searching for a cost imposed on males and females in the polyandrous line we compared fitness parameters of females and males in the two selected lines and male preference to monadrous and polyandrous females.

19

The role of male-male interactions in female reproductive decisions

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Conspicuous male advertisements signals play a key role in female choice of social and copulation partners. In species where males engage in male-male interactions, females may eavesdrop on such interactions and be able to directly compare competing males with little costs. However, little is known about what kind of information females may gather about males when eavesdropping, whether females change their behaviour in the long-term in response and whether reproductive decisions based on male performance in such interactions lead to benefits for females. Here we explore the role of eavesdropping on male song interactions in a population of wild great tits (*Parus major*) combining data from a recorder array, microsatellite genotyping, cross-foster experiments, interactive playbacks and automated radio tracking. We present results on the long-term spatial responses of females to male interactions and male traits that may be honestly indicated by male performance during such contests, providing new insights into the role of male song interactions for female reproductive decisions.

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Fitness consequences of female alternative reproductive tactits in house mice

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Alternative reproductive tactics (ARTs) are defined as discrete differences in morphological, physiological and/or behavioural traits associated with reproduction, which occur within the same sex and population. House mice (*Mus musculus domesticus*) provide a rare example for ARTs in females, which can either rear their young solitarily, or together with one or several other females in a communal nest. We assessed the fitness consequences of communal and solitary breeding in a wild population to understand how the two tactics can be evolutionarily stable. Females switched between the two tactics, pointing towards them being two tactics within a single strategy. Communal breeding resulted in reduced pup survival and negatively impacted female reproductive success. Older and likely heavier females more often reared their litters solitarily, indicating that females use a condition dependent strategy. Solitary breeding seems the more successful tactic and only younger and likely less competitive females might opt for communal nursing, even at the cost of increased pup mortality. This study emphasizes the importance of analysing phenotypic plasticity and its role in cooperation in the context of female ARTs.

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Causes and consequences of baboon (*Papio ursinus*) urban-foraging in Cape Town, South Africa

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Human-induced environmental changes present both opportunities and challenges for wildlife. While many individuals, populations and species are negatively affected by change, some modify their behaviours (within their morphological and physiological constraints) and take advantage of new opportunities presented in human-changed landscapes. 'Urban-foraging' is one such behavioural modification, enabling individuals to exploit high energy, human-derived foods (e.g. crops and food-waste), but this behaviour can also result in conservation conflicts and challenges for the management of wild animal populations. In the Cape Peninsula of South Africa, chacma baboons (*Papio ursinus*) live in spatial overlap with humans and commonly urban-forage: 'raiding' fruiting trees, residential and commercial properties, even taking food directly from people. The City of Cape Town hires a management programme that employs field-rangers to effectively 'herd' the baboons out of the urban space. Here, we investigate the causes and consequences of urban-foraging for a baboon troop living at the urban edge. We combine behavioural data from custom-built tracking collars (for n=16 adults, recording high resolution GPS and acceleration data) with non-invasively assessed physiological stress levels and nutritional state, and information on environmental risks and rewards. We present preliminary findings based on individual trajectory data collected at 1Hz resolution over several months, and explore the factors that predict the frequency and duration of individual urban-foraging. Finally, we discuss our findings in the context of current management practices for reducing human-baboon conflict on the Peninsula, and consider our results in understanding how urban-foraging species manage the costs and benefits of living alongside humans.

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Movement tracking reveals that parrots exploit cyclic, human-derived food opportunities in urban habitats

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For animals that partly exploit human-derived food, urban environments present a complex food landscape. This includes both geographical and temporal aspects, such as the flow of people having lunch in city parks over the weekend or provisioning from residential balconies before work. Predicting the availability of such resources in time and space represents cognitive and navigational challenges. Here, we present pioneering work that aims to uncover cognitive processes underlying the navigational and foraging decision making of sulphur-crested cockatoos (*Cacatua galerita*), a large social parrot that has successfully invaded or persisted in human-modified habitats across Australia. Using over 30,000 record data from the long term citizen science project 'Wing-tags' we create a dynamic representation of cyclic food availabilities arising from recreational bird feeding in central Sydney, and match these with 2 years of high frequency GPS data collected on 8 sulphur crested cockatoos. Birds' activity daily patterns coincide with collective patterns emerging from human activities. In addition, birds show site fidelity and regular directional flights to specific locations in dense urban areas, suggesting knowledge and memory of regular, geographically specific foraging opportunities. Building on these maps, we discuss the role of cognitive processes such as memory and mental maps when navigating across urban landscapes to find food. Our work represents a novel representation of the city pulse from a human and a bird point of view, and advances our understanding of how cognition can facilitate some species to coexist and interact with humans in large cities.

23

The geometry of decision making

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From genetic and neural networks to ant colonies and wildebeest herds, collective behaviour has evolved across levels of biological complexity. In contrast to most artificial systems, decentralised control is often a signature of such systems. For animals in the natural world, survival often depends on the behavioural rules that individuals adopt and the decisions they make in response to the location of conspecifics, resources and threats in their environment. Most of the decision-making literature in both animal behaviour and neuroscience is limited to individuals exposed to a two-choice context. But this is not necessarily true of freely-moving animals in the wild. Individuals may encounter multiple options and rewards rely on the animal choosing the right option within reasonable time. My work elucidates how the brain breaks symmetry when faced with an n-choice decision scenario and how this links to consensus decision-making, previously described in fish schools and baboon troops. By linking decision-making at these two scales i.e. individual and group, I reveal unifying principles of decision-making in Euclidean space.

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Plastic pollution impairs shell selection behaviour in hermit crabs

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Microplastics (plastics <5mm in diameter) present a major threat to marine biodiversity, reducing survival, fecundity, and growth rates in a range of species. However, the behavioural and cognitive impacts of plastic pollution are poorly understood. This study used shell selection behaviour in hermit crabs (*Pagurus bernhardus*) as a model system to investigate effects on cognition. We hypothesised that microplastic exposure would impair shell selection behaviour, measured as lower rates and higher latencies of contacting, investigating, and entering an optimal shell. To test this, 64 wild-caught female crabs were kept in tanks containing either 50g polyethylene microbeads (plastic treatment; n=35) or no plastic (control; n=29) for five days. Subjects were then moved into suboptimal shells, acclimated to an observation tank, and offered an optimal alternative shell. Their behaviour was subsequently recorded for 30 minutes. As predicted, fewer crabs in the plastic treatment contacted (χ^2=7.401, p=0.007) and entered (χ^2=5.343, p=0.021) the optimal shell, compared to control animals. Contact latency was also greater for the plastic treatment (plastic median=1800s, IQR=1296-1800s, control median=948s, IQR=178-1800s, U=290, p=0.002), although there were no differences in either investigation time (plastic median=80.5s, IQR=63-218s, control median=129.5s, IQR=70-198.5s, U=97.5, p=0.401) or latency to enter the optimal shell (plastic median=634s, IQ=257.5-1503.5s, control median=565s, IQR=276.5-1213.5s, U=83, p=0.625). These results demonstrate that microplastic exposure can be detrimental to hermit crab shell selection. More research is necessary to establish whether similar effects are observed in natural environments and other species.

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Sensory biology in ballooning spiders

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Some spiders and other wingless arthropods, such as caterpillars and spider mites, disperse aerially over hundreds of kilometres by ballooning. Technically a misnomer, ballooning involves the arthropod releasing strands of silk on which sufficient forces act to provide rapid lift and take off. Air movement from wind, thermals and their associated drag forces can generate the lift to make these animals air-borne, however an alternative hypothesis is that electrostatic forces could generate lift. Atmospheric electricity, or the atmospheric potential gradient (APG), is present at all times and varies with weather patterns; from around +120V/m on days with clear skies to up to ±10kV/m under storm clouds and mist. Under ecological conditions spiders and other arthropods will be subject to both air movements and electric fields provided by the APG. Here, the ability of spiders to detect and respond behaviourally to electric fields is tested. I show that spiders attempt to balloon in response to electric fields alone and I explore how wind and e-fields can interact to trigger ballooning behaviour. The discovery that terrestrial organisms can detect electric fields at atmospheric levels opens up an entirely new field in sensory biology, demanding the use of technology from the physical sciences to make measurements possible. Understanding how ballooning behaviour is triggered, and in which ecological conditions, will provide a new tool for understanding the distribution and abundance of arthropod species that use ballooning to disperse.

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Altruistic bet-hedging in an arid zone cooperative breeder

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Altruistic species are globally associated with arid and unpredictable environments, highlighting the importance of environmental conditions as a driver for the evolution of altruism. Recent theoretical work suggests that when the environment is unpredictable, altruistic behaviours can be selected to reduce variance in fitness rather than increases in mean fitness, as traditionally thought. This new hypothesis, so-called altruistic bet-hedging, provides a novel framework to test the mechanisms by which environmental conditions promote the appearance of altruism. However, the predictions of altruistic bet-hedging theory have not been explicitly tested yet. In this talk we outline our research showing that environmental and cooperative factors in white-browed sparrow weaver societies have effects on reproductive success that closely match those predicted by altruistic bet-hedging theory. We find that the presence of (female) helpers reduces variance in reproductive success but not its mean. Furthermore, we explicitly show that these differences in reproductive success are in part explained by how the presence of female helpers interacts with environmental conditions. Our results provide rare evidence suggesting that altruistic bet-hedging may explain cooperation in an arid zone bird. Furthermore, our findings reveal hidden costs of cooperation and highlight that the expected overall effect of cooperation on reproductive success will depend on the relative frequency of different environmental conditions. Variation in the relative frequency of environmental conditions due to geographical factors or climate change is expected to modify the extent to which selection for cooperation arises from effects on the mean or variance.

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Behavioural traits that define social dominance are the same that reduce social influence

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The traits that define social dominance in many societies – aggression, coercion, and influence over group decisions – may be the very traits that reduce influence in other contexts. Here we examine the behavior and influence of dominant and subordinate male cichlid fish in different contexts. We find that under standard social conditions, dominant males are the most aggressive group members and concomitantly have the greatest influence over group behavior. However, in a more complex group scenario – responding to a simple association task – dominant males have the weakest influence over group behavior. Instead subordinate males, with low aggression and little influence over typical group behavior, have the greatest influence over their groups in the context of the association task. Although subordinate males had little behavioral connection with other group members, they were highly connected both spatially and visually – likely important types of connection when responding to a visual task. Moreover, the behavioral stimuli that caused group movements had different signal-to-noise ratios for dominant and subordinate males. Response to the association task was characterized by a rapid, directional swim toward the light cue, which was kinematically different from normal swimming, but similar to the aversive chasing frequently displayed by dominant males. In contrast, subordinate males only displayed this behavior in the association task. We conclude that it was the very behaviors that made dominant males influential in one context that caused them to lack influence in another.

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Epigenetics and environmental change: adaptation versus constraint

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If organisms are to persist in the face of climate change, they must be able to deal not only with increasing temperatures, but also greater climatic variation. One of the primary ways animals cope with environmental change is through phenotypic plasticity, the ability to respond to environmental cues through phenotypic adjustment. For many animals, plasticity during development can influence behaviour and fitness later in life, both positively (adaptation) and negatively (constraint). Using superb starlings (*Lamprotornis superbus*), which inhabit a range of East African environments where rainfall varies within and among years, I will explore the molecular mechanisms that underlie plasticity in the genome in the form of epigenetic change. Specifically, I will examine how patterns of DNA methylation across the starling genome vary with rainfall during development, discussing genes that show signatures of adaptive capacity versus those that instead show signatures of being constrained by early life conditions. I will then compare patterns of DNA methylation across the genome from birds collected along an ecological gradient spanning hundreds of kilometers that varies in the degree of rainfall variability and predictability. Together, these two studies will not only illustrate the different ways that environmental conditions shape patterns of DNA methylation across the genome, but they will enable me to develop an evolutionary framework for integrating ideas of adaptation and constraint in the context of climate change and behavioural epigenetics.

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Transgenerational effects of simple and complex environments on behaviour in zebrafish

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Phenotypic plasticity is a fundamental mechanism by which organisms can adapt to cope with environmental change, such plasticity represents a short-term mechanism of adaptation within the lifetime of an individual. However, recent evidence suggests that the inheritance of acquired traits via epigenetic mechanisms may also represent a mechanism for adaptation to certain environments over multiple generations. There are many outstanding questions regarding the adaptive relevance of these mechanisms, the environmental contexts under which this type of inheritance may occur, the persistence of such effects and how common they are. We examined the inheritance of acquired behavioural traits using a combination of environmental manipulations and automated animal tracking with *Danio rerio*. Adult male zebrafish were exposed to simple or complex physical environments and their behaviour was quantified using automated video tracking and custom analysis scripts. Males of both groups were then bred with separate unmanipulated females, and behaviour of the F1 offspring was quantified both as larvae and as adults. Social behaviour, activity and anxiety-like behaviour were all influenced by the environment in the parents, but we also found evidence for transmission of behaviour to F1 offspring. We then repeated the manipulation again using males from this F1 offspring cohort and examined the inheritance of traits in F2 offspring with varying parental and/or grand-parental environmental experience. These results suggest that paternal environmental experience can be inherited non-genetically in zebrafish, affecting behaviour in subsequent generations.

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Adaptive motor control: Slope-dependent modulation of muscle co-contraction in freely walking stick insects

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Terrestrial locomotion in a variable and unpredictable environment requires animals to adjust their limb movements appropriately. For example, the ability to cope with disturbances like changes in substrate slope is crucial for locomotion at intended speed and direction. Negotiating inclines is particularly interesting as it is associated with changes in load distribution across the body. Flexibility in motor control is thought to be achieved by either utilizing distinct motor patterns, or by closed-loop control through sensory feedback. Mammals, for example, adjust their motor output in anticipation of an incline and use functionally distinct transition strides between level and slope walking (Gottschall and Nichols, 2011). So far, slope-dependent changes in insects have been studied mainly under steady-state conditions, thus neglecting the dynamics of adaptation in response to changes in load distribution. Here, we investigated how freely walking stick insects (*Carausius morosus*) mastered a step change in walkway slope (±45°). For this, we simultaneously recorded their whole-body kinematics and hind leg muscle activity. We moreover used a simplified mechanical model to estimate the varying mechanical demand due to slope transitions. Our results suggest that these transitions involve only little kinematic adjustments, but a considerable reduction in muscle co-contraction associated with shifts in how ground reaction forces distribute. Since the observed changes occurred gradually with each subsequent leg stepping onto the incline, we conclude that stick insect motor adaptation to inclines is achieved reflexively and continuously, depending on the ongoing load sensory feedback, rather than through switching between pre-wired distinct motor programs.

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Dynamical network formation of *C. elegans*

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Understanding physical rules underlying collective motions requires perturbation of controllable parameters in self-propelled particles. However, controlling parameters in animals is generally not easy, which makes physical rules underlying animals' collective behaviors elusive. Here, we find that a conventional model animal, *C. elegans*, collectively forms dynamical networks of bundle-shaped aggregates with simple physical rules. We investigate the dependence of the *C. elegans* network formation on various extrinsic parameters (material of substrate, ambient humidity and density of worms). Taking advantage of well-established *C. elegans* genetics, we also control intrinsic parameters (genetically determined motility) by mutations and by forced neural activation via optogenetics. Furthermore, we develop a minimal agent-based model that reproduces the dynamical network formation and its dependence on the parameters, suggesting that the key factors are alignment of worms after collision and smooth turning. Our findings imply that the concepts of active matter physics may help us to understand biological functions of animal groups.

Ref, Sugi* et al. Nature Commun, 2019; Sugi* et al. PNAS, 2014; Sugi et al. Nature Neurosci, 2011

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Bats adjust their mouth-gape to rapidly narrow their acoustic 'field of view'

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Echolocating bats are renowned for their ability to control the sensory information that they acquire. By rapidly changing their echolocation signal design and timing, bats can adjust the rate and accuracy which they acquire information about the environment. Much less is understood about bats' ability to control the spatial aspects of their emission, that is their ability to control the sector of space which they scan using a single emission (beam forming). We used a large (wideband) microphone array and a high-end tracking system to reconstruct high resolution beams and mouth movements of *Pipistrellus kuhlii* bats as they were searching for and landing on a target in a large flight room. We show that bats rapidly narrow their bio-sonar field of view when scanning a target. On-target horizontal sonar-beams were ~23 degrees narrower than off-target beams. By directly measuring bats' mouth-gape, we found that this beam adjustment was mediated by changes in the mouth gape: bats opened their mouth to narrow the beam and vice versa. Acoustic simulations confirmed these results and also suggested that the bats narrowed the vertical beam-width by ~50 degrees. The bats used the same sensory strategy in the presence of loud masking noise implying that beam adjustments are not used for dealing with noise. The function of the narrowing of the beam was probably to improve signal-to-noise-ratio which increased by at least 60%. The narrowing of the beam-width could also play a role in improving spatial localization.

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Neural mechanisms of simple grouping behaviour: nonapeptide regulation of shoaling in fish

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The nonapeptides are a highly conserved family of neuropeptide hormones that have been repeatedly shown to regulate social behaviours across vertebrate taxa. In mammals the nonapeptides oxytocin and vasopressin have been shown to play key roles in complex behaviours such as pair bonding, social recognition, parental behaviour etc. However simple grouping behaviour is often difficult to study in many mammals, and recent research in other taxa has started to explore the role of nonapeptides in grouping behaviour. We have examined the role of nonapeptides in shoaling behaviour in different fish species and populations, using behavioural, pharmacological and neurobiological approaches to investigate how the teleost nonapeptides isotocin and vasotocin influence shoaling behaviour. In guppies, we have shown that administration of isotocin increases shoaling tendency, while vasotocin reduces it. We have shown that increases in shoaling tendency seen in predator-exposed guppies are associated with changes in vasotocin signalling and sensitivity. In zebrafish, we have found that increased environmental complexity leads to increased shoaling tendencies within a few weeks, and that this behavioural shift is associated with increased isotocin neuron numbers, specifically in the magnocellular portion of the pre-optic area. Unlike in mammals, behavioural phenotypes in fish seem to be associated with changes in nonapeptide signalling, rather than nonapeptide receptor distribution. This work indicates that the role of nonapeptides in social behaviour is conserved across vertebrates, but with important mechanistic differences between taxa, and that nonapeptide signalling plays a critical role in simple grouping behaviour in vertebrates, as well as complex social behaviour.

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Escape from threat in the presence of obstacles

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Having a functional understanding of the world is fundamental for choosing and executing adaptive actions. It is not known how the mammalian brain builds and represents this understanding. Here we address this problem by studying a set of ethological actions that rely on knowledge that animals have about their spatial environment. Using new behavioural paradigms, we investigate the strategies that mice use to escape from imminent threats when there are obstacles on the way to their shelter. We find a hierarchy of strategies, in which mice first follow innate navigational rules that lead to suboptimal escape paths. Next, they learn from the spatial statistics of these inefficient escapes: in subsequent trials, they run directly to an intermediate goal that provides access to the shelter, such as an edge of the obstacle. At this stage, previously taken escape paths are also converted to memorized trajectories; when the environment changes acutely, there is a balance between exploiting these known routes and finding new, efficient paths to the shelter. These results identify strategies that mice use to select escape routes based on an understanding of their surroundings, and they provide a starting point for investigating how the brain uses internal models of the world during natural behaviours.

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Inter-group dispersal in Vulturine guineafowl

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Dispersal is one of the primary drivers of population dynamics, connectivity, and gene flow. For social species, dispersal behaviors are not only dependent on the physical properties of their environment, but also on the social landscape. Many species use social information (e.g. conspecific densities) to decide when to depart and where to settle, possibly as an indicator of underlying habitat quality or to avoid competition. However, for group-living species, the underlying habitat is likely less important to dispersers than the distribution and social structure of groups. How do subadults disperse through the social landscape? For example, individuals who are part of more cohesive social groups, or who receive more affiliative interactions are less likely to disperse. Similarly, more cohesive social groups may be more resistant to the immigration of new individuals, thus affecting settlement. The Vulturine guineafowl (*Acryllium vulturinum*) is a highly-gregarious bird species which lives in highly-cohesive groups. Using a 2-year dataset comprising over 800 individuals spanning 18 groups that are permanently tracked using GPS tags, I quantify how inter-individual interactions, and the history and dynamics of interactions among groups, predict which individuals disperse and where they disperse to. These unique data provide some of the first insights into both the large-scale movements of individuals across social landscapes and the fine-scale social that dictates the decisions that individuals make.

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Individual information access resulting from fine-scale movement decisions

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Animals must constantly make decisions that affect their fitness (e.g. where to go, what to eat, when to be vigilant). In order to make beneficial decisions, they must collect and integrate information and from their physical surroundings and social partners. In complex natural environments an animal's fine-scale behavior can strongly influence its access to such information. To study this, we used drones to film free-ranging zebra herds in Kenya and create 3D models of the surrounding environment. Using novel analytical methods, we extracted movement and behavioral data from these videos, and reconstructed individuals' visual fields. Here we present the results of our analyses, in which we explore how individuals' fine-scale movement and behavioral decisions affect their visual access to social and environmental information. By comparing observed paths to randomized and optimized paths, we explore the extent to which individuals prioritize visual information access as they move through complex habitats. We also consider the implications of individual strategies for group-level phenomena such as collective detection and information transfer.

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The influence of social relationships on leader-follower decisions in highly dynamic bird flocks

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In group-living animals, pre-existing social relationships can underlie leader-follower decisions. Primates that live in stable groups, for instance, tend to follow their preferred affiliates during collective movements. However, such highly stable groups are relatively rare in nature; it remains therefore unclear whether such leader-follower decision rules could also take place in more fluid social systems. Here, we investigate the extent to which social relationships predict leader-follower events in collective movements of colonial birds that form fission-fusion flocks. We used a high-resolution system to track 6 flocks of 28 captive zebra finches (*Taeniopygia guttata*), using the precise record of their locations over time to calculate their social association strengths with others (i.e. their social networks) and their fine-scale movements over time (i.e. leader-follower events). Then we used generalized linear models to relate previous social associations with current leader-follower events during collective movements. Our results indicate that the probability to follow an individual is positively correlated with social association strength and negatively correlated with the distance between leader and follower prior to the movement taking place. These findings corroborate predictions of self-organizing collective movement in which individuals tend to react to their nearby conspecifics; but they also highlight that even in fluid social systems individuals can have a higher probability to follow those that they are more strongly associated with. Our study suggests that the 'follow-a-friend' rule can be detected not only in species that live in stable groups but also in more dynamic social systems.

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The evolution of menopause in resident killer whales (and other interesting animals)

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Why females of some species cease ovulation before the end of their natural lifespan is a longstanding puzzle in life-history evolution. In humans, as well as some natural populations of toothed whales, reproductive aging occurs much faster than somatic aging and females exhibit prolonged post-reproductive lifespans (PRLSs). Determining the mechanisms and functions that underpin PRLSs has proved a significant challenge. Here I summarise our work, bring together both classic and modern hypotheses proposed to explain PRLSs and life-history evolution and discuss their application with particular reference to our studies of killer whales. In doing so I highlight the need to consider multiple interacting explanations for the evolution of PRLSs and discuss the key role of social structure.

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Movement patterns and leadership in a multilevel social group

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Patterns in animal movement arise from interactions between moving individuals, and hence are modulated by social relations within the group. Thus, the spatial distribution and movement patterns of individuals often reflect the structure of the society the animals are living in. The occurring particular movement patterns may also influence the dynamics of leading within the group. To investigate the relationship between movement patterns and leadership, we observed the collective motion of free-ranging Przewalski horses in Hortobágy National Park, Hungary. These horses are especially suitable to such a study because in this reserve they live in a complex multilevel society: harems unite in a large herd. In this study we used novel methods, since we need the continuous and simultaneous position data at high frequency for wild animals in natural environment. Our observational method is based on aerial videos of two drones, one provides high resolution motion data for all animals in the herd, while the other ensures individual recognition. In this way, we collected trajectory data regarding the daily movements of around 250 individuals at the same time, while knowing the identity of all of them. Using the data generated from the aerial footage, we are studying the motion patterns and leadership dynamics inside the harems and inside the whole herd. Since all the horses are recognised and their life- and harem history was recorded regularly for the past 20 years, motion data can be related to many individual and group characteristics.

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Conflicts of interest and collective decision-making in white-faced capuchins (*Cebus capucinus*)

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How do groups of individuals decide where to go and what to do? To obtain the benefits of sociality, animal groups must remain cohesive, reaching consensus and coordinating important daily activities like foraging. However, foraging strategies of individual group members often vary, creating conflicts of interest about foraging choices. When conflicts of interest about when and where to feed exist in a group, some individuals must compromise their preferred behavior, presumably at a cost to themselves. This study extends the marginal value theorem to individuals living in stable social groups to generate predictions about the mechanisms underpinning how groups reach consensus. Using a six-month study of two white-faced capuchin monkey groups (*Cebus capucinus*) on Barro Colorado Island, Panama, we examine individual differences in optimal patch departure time and how these translate into collective decisions. We test the hypothesis that dominance, size, and age impact how long individuals prefer to remain in a foraging tree, creating conflicts of interest over when to leave. Using the focal tree method on group feedings in Attalea butyracea palms, we calculate exact individual feeding rates for all group members in each palm. These feeding rates generate individual foraging gain curves that predict optimal departure times. We further analyze individual attempts to initiate group movement to understand who exerts influence on group decisions. Results indicate individuals differ in their preferred departure times and group decisions are shared between adults. Together, this captures important elements of group decision-making in social primates: when to go and who decides.

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Drones and Deep Learning Reveal Visually-mediated Collective Decision Making in the Wild

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We use video recording drones and custom built computer vision algorithms to not only automatically record the location of all individuals in ungulate herds in the wild but also detect nine body key-points, things like front of the head, shoulders, and tail, for all individuals in the group. We then embed this information in finescale georeferenced 3D landscape maps with centimeter level precision. We study herds of plains zebra, Grevy's zebra, impala, and african buffalo in central Kenya. Using a relay of drones we record herds for up to an hour during which time we observe the animals in an undisturbed state and then purposely walk toward them on foot to create a disturbance they detect and respond to. Afterwards we use an additional drone to create 3D maps of the exact area the animals moved through (sometimes over more than a square kilometer) with pixel resolution of a few centimeters. Since we know each individuals location, head position and direction, and their exact position within the environment, we study the role visual communication plays in group decision making in complex environments under heavy predation risk and observe individuals' strategies for optimizing the acquisition of both social and environmental information while also effectively foraging and remaining safe from predation.

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Energy saving in fish school

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Movement through fluids imposes steep energetic costs on organisms that swim, glide, and fly. It has long been proposed that group-living species minimise these costs through collective coordination, but while this appears to be true for flocking birds, there is little evidence that schooling fish coordinate their movement to save energy when swimming. In addition to scarce direct evidence, we also lack a biologically-plausible theory to describe how fish should behave when obtaining hydrodynamic benefits from others. Most models of collective energy savings are overly simplistic or make restrictive, unrealistic assumptions about spatial positions, which tend to be highly dynamic in real groups. Consequently, despite an abundance of predictions that energy saving is possible, we have yet to reconcile existing theory with natural behaviour. To address these problems, we employ an integrative experimental and theoretical approach. First, we use a physical model of fish-like robots to derive a new, foundational theory of hydrodynamic interactions that generalises to any group structure. Our model reveals that regardless of the specific spatial arrangement, fish can obtain energetic benefits from a leading neighbour by adjusting their swimming pattern using a simple, linear relationship. We further conduct experiments with pairs of freely-swimming goldfish (*Carassius auratus*) and find that this species engages in the same dynamical vortex phase matching predicted by our theory to save energy. Our results offer important insights into the ecology of schooling fish, and our theoretical model could be readily applied to the development of efficient underwater autonomous vehicles.

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Deep attention networks reveal the rules of collective motion in zebrafish

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A variety of simple models has been proposed to understand the collective motion of animals. Simple models can be insightful but lack important elements necessary to predict the motion of each individual in the collective. Adding more detail increases predictability but can make models too complex to be insightful. Here we report how the modular structure of deep attention networks can obtain a model of collective behavior that is simultaneously predictive and insightful. Our model describes zebrafish pairwise interactions, *Danio rerio*, as approximately repulsive, attractive or as alignment, but only when moving slowly. At high velocities, interactions correspond only to alignment or alignment mixed with repulsion at close distances. The model captures aggregation of information from different neighbours as a weighted average. Weights are higher for neighbours that are close, in a collision path or moving faster in frontal and lateral locations. These weights effectively select a dynamical number of neighbours, from a single one to up to 12, often changing in less than a second. By fitting the model to groups of fish of different ages, we explored the ontogeny of collective behaviour. Prediction accuracies are higher for older fish. Interaction maps show stronger attraction and orientation in older fish, with smoother attention maps. We also explored the effect of group size and habituation to the environment on the rules of collective behaviour.

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idtracker.ai: tracking all individuals in small or large collectives of unmarked animals

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Understanding of animal collectives is limited by the ability to track each individual. Determining animal trajectories from video recordings faces the problem of maintaining correct animal identifications after individuals touch, cross or are occluded by environmental features. We present idtracker.ai, an algorithm and software that extracts all trajectories from video, with high identification accuracy for collectives of up to 100 individuals. First, a species-agnostic preprocessing extracts images from the video. Then, a first convolutional network detects when animals touch or cross, and a second convolutional network identifies the animals along the video. Training examples for both networks are safely extracted using a set of heuristics without humans in the loop. A training and identification protocol adapts to the conditions of the video and tracking difficulty. Post-processing steps are applied to ensure the continuity of the trajectories. Thanks to the transfer learning capacities of the convolutional networks, idtracker.ai can be used in different ways to match animal identities across videos. The modularity of this open-source and free software tracking system allows researchers to use it and adapt it to their needs. In particular, we show how we use idtracker.ai and a predictive model based on deep attention networks to study information transfer across individuals in groups of juvenile zebrafish.

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Individual identification using deep learning in wild birds

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Individual identification is essential to most animal studies in ecology, evolution and conservation. To date, this has been achieved mostly through methods relying on marking individuals (e.g. colour rings) and using human observers for data acquisition. While presenting several advantages, these methods can be time consuming and labour-intensive, thereby hampering high rates of data collection. Recent technological and analytical advances, such as RFID and deep learning can help to overcome these limitations by automatizing data collection and analysis. Here, we present a method based on photos that allows the individual identification and behavioural study of a small passerine bird, the sociable weaver, *Philetairus socius*. First, we describe an automated method (based on RFID) for efficient collection of large samples of individually labelled images of birds in the wild, which are required for training convolutional neural networks (CNNs). Second, we go through the process of training a CNN to build an accurate classifier of the focal individuals. Finally, we test the generalization capability of our models by predicting the identity of the birds from images that were collected with different cameras and in different contexts from the ones originally used for training the CNNs. We show that it is possible to identify birds with >90% accuracy, even when the conditions of the training datasets differ from the images to which the classifier can potentially be applied. These results provide a practical solution for collecting large training datasets and illustrate the potential use of CNN for individual identification in wild populations.

3D-tracking collective escape in wild groups of Damselfish

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In animal collectives, it might only take one or a few individuals to detect a threat in order to trigger a collective escape at the level of the group. For animals living in hierarchically-structured groups, it remains unclear whether, and how, dominance relationships shape the way information spreads. I will present how we investigated the impact of social hierarchy on collective sensing in socially-structured groups of damselfish *Dascyllus marginatus*. In the field, we experimentally triggered collective escape responses using a loom stimulus projected on an iPad. This allowed us to create situations where a limited number of individuals had direct access to the information. Using multiple cameras, we tracked in 3D the movements of all group members during these experimentally-induced collective escapes. In order to disentangle between private and social access to information, we then computed the visual connections between all the individuals and the loom stimulus. I will discuss whether the number and the social status of the initiator(s) affect the speed at which information spreads within the group, and the intensity of the escape response in the other individuals.

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All you need is statistical physics? Group- vs. Individual-Optimization against Predator Attacks

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Animal collectives can be framed as an ensemble of agents following identical rules modeled as social forces. This framing is also common in statistical physics, which suggests that general principles from statistical physics also hold for the description of animal collectives.

One of the most prominent ones is that a system at a transition from an ordered to an unordered state has the strongest response to an external global field. Based on this concept of maximal response at the transition it was conjectured that natural systems should evolve to this transition ('criticality'), i.e. represent examples of self-organized critical systems.

Here we investigate the validity of this concept using an individual-based model for a collective of agents being attacked by a single predator with different attack schemes. We find that under group-level optimization the order-transition is favored. However, not improved reaction but spatial structure is the main driver. On the other hand, under individual-level optimization, i.e. natural evolution like optimization, the collective is not showing self-organized criticality but rather evolves into the ordered phase away from the transition. The main cause of this trend in evolution is the spatial self-sorting of agents according to their parameters.

Our work shows how difficult it is to translate concepts from statistical physics to heterogeneous and spatially explicit biological systems. However, we also emphasize how important and fruitful the feedback between the two disciplines can be.

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La Olá' waves of the sulphur molly: adaptive anti-predator behavior of an extremophile fish

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The ability to detect and react towards a potential predator is crucial for animals as failure to respond is usually fatal. However, anti-predator responses often come at a cost and reactions while no or only inactive predators are present will reduce the prey's overall fitness. In Mexico, sulphide-rich and severely hypoxic springs are colonized by the endemic sulphur molly (*Poecilia sulphuraria*). To cope with these physicochemical stresses, sulphur mollies perform aquatic surface respiration, resulting in the build-up of large aggregations directly at the water surface, where they are particularly vulnerable to avian predation. Following a bird attack, fish schools produce a series of synchronized collective waves by repeatedly diving down in a cascade-like manner. As diving into the hypoxic water column is costly, fish may have evolved mechanisms to distinguish between potential threats and harmless environmental disturbances such as flyovers of non-predatory birds. We found that only specialized piscivores like kingfishers and egrets produce large-scale, repeated collective responses of the sulphur mollies. In a laboratory experiment, we presented fish with artificial disturbance cues and found that bimodal stimulations consisting of a combined visual and acoustic cue induced significantly stronger escape behaviors than either cue alone. Most piscivorous birds produce both visual and acoustic cues during their hunting, while most non-dangerous disturbances are only associated with a single cue. Thus, we assume that sulphur mollies use predator-specific cue sets to distinguish dangerous from non-dangerous disturbances and react only to the latter.

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Anti-predator costs and benefits of leadership: experimental evidence using virtual prey attacked by real predators

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The major cost of leadership in moving animal groups has long been assumed to be predation, with individuals leading from the front of groups being targeted more often by predators. Nevertheless, empirical evidence for this is limited and experimental tests are entirely lacking. To avoid confounding effects associated with observational studies, we presented a simulation of virtual prey to real fish predators to directly assess the predation cost of leadership. Prey leading others are at greater risk than those in the middle of groups, confirming that any benefits of leading may be offset by predation costs. Importantly, however, followers confer a net safety benefit to leaders, as prey leading others were less likely to be attacked compared to solitary prey. We also find that the predators preferentially attacked when solitary individuals were more frequent, but this effect was relatively weak compared to the preference for attacking solitary prey during an attack. Our results suggest that goal-orientated individuals, i.e. potential leaders, are under selective pressure to maintain group cohesion, favouring effective leadership rather than group fragmentation.

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When and how: temporal patterns, defensive behaviours and adaptive benefits associated to male parental care in the glassfrog *Centrolene savagei*

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Recording information about adaptive benefits and variation of parental investment in glassfrogs, is important for a better understanding of the evolutionary behavioral ecology in anurans. In this study, we recorded variations in parental investment by males of the glassfrog *Centrolene savagei* at two temporal scales; and we performed field experiments to simulate risks of predation by small invertebrates, to test the level of aggression of males caring eggs. Between February 2016 and November 2018, we monitored 87 males and 154 egg clutches in a population of *C. savagei* in the Central Andes of Colombia. Parental investment was higher at night than at noon, and it decrease as embryos develop and become more independent. Males caring eggs exhibit higher levels of aggression than solitary males, by biting and kicking with their legs the brush tip when simulating predation attacks; moreover, these males also spent more time tolerating the stimulus before flee. Our results show that male parental care behavior in *C. savagei* is adaptive. However, parental investment is a plastic behavior and varies across embryonic development, during the day and likely across seasons or populations with different environmental conditions.

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Swarm intelligence and the avoidance of parasites in schooling fish

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Disease transmission and parasitism is thought to be one of the major costs of group living. Nonetheless, when many individuals interact, a variety of behavioral patterns emerge enhancing information processing and the ability to discriminate subtle differences in the environment. With this study, we explore how groups of fish cope with the presence of an ectoparasite and if group living facilitates disease avoidance. At the individual level, fish are manually infected and monitored for the metabolic costs and behavioral effects of the infection using physiology tests in a swim tunnel. At the group level, we use individual tracking methods and reconstruct collective dynamics and individual movement characteristics that emerge in groups containing both uninfected and infected individuals. Specifically, we ask whether groups of uninfected fish can detect and move away from infected individuals, for example using wisdom-of-the-crowd mechanisms, or via distributed mechanisms. Overall, we aim at quantifying physiological and behavioral characteristics to better understand the relationship between individual and group-level information processing in the context of antiparasite defense.

Context dependent sociality across foraging strategies and behaviours in a colonial seabird

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Animals experience consequences and benefits from group living, thus social behaviours should be favoured only when the benefits of sociality overcome the costs. Indeed, many animal groups exhibit fission-fusion dynamics, in which groups form and separate over time, with individuals varying in their use of social behaviours. If the costs and benefits of sociality differ between behavioural contexts and external condition, individuals may alter their social behaviours in a context dependent manner. However, current studies of animal sociality have generally focussed on single behaviours in isolation. Recent advances in multilayer social network methods provide a robust way to consider the multifaceted nature of sociality. To understand the factors driving individual variation in sociality we simultaneously GPS tracked 85% of all breeding individuals from a small colony of Australasian gannets (*Morus serrator*). Individuals from this colony exhibit location specific (bay-restricted and open-strait) foraging strategies, allowing us to address the hypothesis that sociality will vary with environmental contexts. We also examine sociality across three related behavioural contexts; coordination at the colony, commuting and foraging. During foraging, individuals socially associate more than expected by chance only during open-strait foraging, highlighting the use of environmentally driven social strategies. We found low overlap in sociality between colony, commuting and foraging behaviours, highlighting some carry-over between these behaviours, but that social foraging primarily occurs separately from other social associations. Through our multidimensional analysis of social movement and foraging we provide a first quantification of individual-level variation in sociality of a colonial species across multiple contexts.

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General rules to predict the outcome of chemotaxis across species

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Many living beings navigate using chemical cues. This behavior, known as chemotaxis, is a key feature of life across several levels: It guides bacteria towards nutrients and suitable niches, it helps immune cells find the pathogenic ones, and steers animals away from predators and towards food, friends and mates.

The physiological and biophysical mechanisms that underlie chemotaxis have been extensively studied. It is however difficult to link the well-studied instantaneous behaviors of chemotacting individuals to the global features that determine the fate of the system, such as the distribution of foragers across food patches. Through a combination of theory and experiments, we aim to link these two levels of description.

Our theoretical work studies how sources of chemoattractants of different densities can be distinguished at a distance. We have obtained two interesting predictions on how this ability is limited by the physical properties of diffusion. First, we find that a difference of orders of magnitude in concentration between two sources may lead to only a small difference in the number of individuals choosing each one. Second, we find a counterintuitive trade-off: Being better at finding resources (i.e. having higher sensitivity to the chemoattractant) may lead to a lower ability to distinguish high-quality sources from low-quality ones.

We test our predictions experimentally using the nematode *Caenorhabditis elegans*, but we aim to develop a general theory to link individual properties to global outcomes, which we expect will be useful across species and contexts.

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Revealing the behavioral algorithms of insect swarms

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Discovering the algorithms that biological systems use to make decisions is a central goal of ethology and neuroscience. Fundamental to our understanding of these systems is the ability to measure and model how individual components cause the emergence of higher-level, collective phenomena. Collective behaviors in animal groups are the product of individual decisions informed by sensory interaction networks, and revealing the network dynamics underlying group decision-making is a key challenge. To achieve a truly comprehensive understanding of behavior and the mechanisms that produce it, detailed and objective descriptions are needed. Recent breakthroughs in computer vision and machine learning have drastically improved the quality and resolution of these measurements, placing these goals within reach.

To reveal the sensory networks underlying locust swarming, we measured the vision and locomotion of marching juvenile locusts (*Schistocerca gregaria*) using a combination of individual tracking, direct estimation of the visual field, and unsupervised pattern-recognition algorithms for classifying behaviors. We then applied Bayesian machine learning methods to automatically derive sensory features that are predictive of individual decision-making and use these features to generate dynamic, multidimensional networks for better understanding how information propagates across groups and causes the emergence of collective behaviors. Results from this work will provide critical understanding of how swarms coordinate their behavior and will inform next-generation models of collective decision-making. This work builds on a growing movement to shift the fields of ethology and neuroscience toward an integrative, data-driven search for parsimonious general principles by leveraging techniques from computer science, physics, and mathematics.

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Social associations and communal nesting decisions in wild house mice: who benefits?

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The benefits of sociality are often not equally distributed, even for seemingly cooperative behaviours, which can influence social decisions and consequently shape animal social systems. An example of such a behaviour is communal nursing in mammals, where multiple reproducing females cooperate to care for their combined offspring. An individual's choice of when and with whom to nurse communally will therefore have important impacts on their fitness. However, the exact mechanisms influencing these decisions and how those choices might subsequently effect reproductive success are still relatively unknown and it therefore remains unclear whether this behaviour is exploitative or cooperative. We examine communal nursing decisions and their effect on individual fitness using a long term dataset of wild house mice (*Mus musculus domesticus*), in which communal nursing is facultative, using detailed data on nest box usage, genetic information and reproductive success. We exploit social network analysis to relate individuals' communal nesting decisions to their previous social behaviour, relatedness and individual traits such as age, allowing us to investigate questions such as how decisions about when to nest communally or not are influenced by group structure, partner availability and the individual traits of partners. We then link these decisions to a female's reproductive success. By examining how social and individual traits combine to influence communal nursing decisions, we gain new insight into how the benefits of communal nursing are distributed and to what extent communal nursing behaviour is exploitative or cooperative.

Footage of the communication function by cheetah at scent-marking sites

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Scent-marking is an essential form of communication, particularly for solitary species, as the information persists and does not rely on individuals encountering one another. Scent-marking conveys information on individual presence/area use, sex, rank and reproductive status. However, not enough is known about such communication in cheetah, *Acinonyx jubatus*, a predominantly solitary felid, and the possible role of scent-marking sites. Using camera-traps, we assessed the behaviour of cheetahs at scent-marking sites, asking how individuals of different demographic and dominance classes use the sites for intraspecific communication. We show that the inferred function of communication at scent-marking sites differs not only by sex but also by rank. Accordingly, females visit the sites infrequently, 8% of all visits, to signal estrus events, while males visit the sites frequently, 91% of all visits. Moreover, among males, dominant individuals scent-marked during 77% of their visits and reacted to a female by vocalizing during 52% of visits, but submissive males neither scent-marked nor vocalized while at the sites. We demonstrate how indirect monitoring can deliver significant behavioural information, and our study showcases the importance of scent-marking sites to cheetah populations, with potential consequences for cheetah reproduction that needs to be further explored.

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Group foraging bats individually discriminate group members based on search-phase echolocation calls

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Animals have evolved diverse strategies to utilize social information for increasing foraging success and efficiency. Echolocating bats can eavesdrop on changes in echolocation calls of nearby bats to gain information about prey availability. A few of these species coordinate flight to search for patchy prey together with their small social group. Yet to access the social information produced by their group members, group foraging bats must be capable of identifying these individuals to maintain contact with them in flight. Here we investigated whether search-phase echolocation calls, produced by bats to scan large areas for prey, can additionally convey individual identity. We caught and recorded search-phase calls of free-flying *Molossus molossus* with known identity. Then we recaptured 25 of these bats from five different social groups and tested them in habituation-dishabituation playback experiments to determine if they can discriminate between individual group members based on their search-phase calls. In playback trials subject bats habituated to calls one group member, then dishabituated to calls of a second group member, and finally rehabituated to new calls of the first group member. Thus they perceived the individual signatures of their group members and not simply the differences between playbacks. Acoustic analysis also supported the presence of individual signatures in search-phase calls. Our results provide the first step in testing the hypothesis that search-phase echolocation calls convey identity to enable *M. molossus* to maintain contact with group members in foraging flight.

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Help thine enemy- the evolution of short ranging signals

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Honest signalling of aggressive intent relies on the proximity risk model in biology. This model assumes that the probability of successful attack is a function of the distance between the contestants and that this distance can be correctly estimated. This later assumption may not hold in nature where contestants have to estimate this distance under noisy conditions. Here I investigate whether short-range ranging signals can be evolutionarily stable under such conditions with the help of a game theoretical model. These signals can help the opponent to estimate the correct distance, thus they can promote honest signalling of intentions. Here I show that ranging signals that help the estimation of distance between opponents can be evolutionarily stable. However, such help only benefits those individuals who are able and willing to attack. As a result, ranging signals in themselves are an honest cue of proximity and in turn they are honest cues of aggressive intent. I give an example: 'soft-song' in birds, and I discuss why these signals are expected to be embedded in the threat display of the species.

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The Cocktail Party Problem: How do field crickets solve it?

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The Cocktail Party Problem arises when multiple signallers signal simultaneously resulting in acoustic masking interference. It is likely to be a major obstacle to effective signalling in loud and dense animal choruses. Crickets are acoustically active insects which call from spatial aggregates and broadcast loud stereotypic and species-specific calls to attract females over long distance. Under these conditions, it is expected that these calls from multiple males may interfere in both spectral and temporal domains resulting in masking. It is reasonable to expect that males must employ strategies to avoid masking and signal effectively. In this study, we examined the conspecific acoustic masking in males of the field cricket *Acanthogryllus asiaticus* by determining their spacing and signal transmission. Playback experiments were conducted to examine acoustic response of focal male towards its real conspecific neighbour in field and towards the simulated masking neighbour under laboratory conditions. We found that males call from spatial aggregates and that their call transmit upto 3 m, thereby demarcating the broadcast area for a given male. Given natural spacing and signal transmission, males on an average have the nearest neighbour at 3 m distance and one acoustic masker on an average. Further, we found that males avoid masking by alternating their calls and modulating their call SPL with their neighbour. Our study provides insights into how males deal with conspecific masking which in turn leads us one step further in understanding how multiple males may signal effectively in the seeming cacophony of a loud chorus.

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Good singers find more eggs in their nest: Song consistency predicts fecundity in blue tits (*Cyanistes caeruleus*)

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Songbirds listen, learn and practice their vocal skills to deliver their conspecific song. The neuro-motor patterns involved demand a fine coordination of respiratory and syrinx muscles, including two independent sound sources. It has been proposed that the accuracy with which a bird delivers its song may indicate the general neuro-motor functioning and therefore be subjected to sexual selection. In addition, females would theoretically be able to assess song consistency quickly in contrast to other song traits such as repertoire size. We studied the song characteristics of individually marked blue tits in a monitored breeding population at Lancaster, UK. We hypothesised that if an individual's vocal control is finely tuned, the sound output of notes of the same type should be consistent. To test that, we designed a custom-made acoustic analysis protocol in R to measure note consistency based on spectrogram correlation. We analysed 14000 individual notes from 1500 songs of 70 individuals (48 males and 22 females). Our results show that male blue tits that performed songs with more consistent notes were paired with females that laid larger clutches of eggs. Furthermore, male song consistency increased throughout the season peaking at the egg-laying period as predicted if consistency was under sexual selection. Finally, vocal consistency in female song is significantly lower than in male song, suggesting female choice might be the evolutionary driver of this trait. In conclusion, we argue that song consistency is a crucial aspect of communication and is likely to play a central role in the evolution of birdsong.

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Sensorimotor perception and integration of multiple-simultaneous visual stimuli in locusts

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In marching insects such as desert locusts, the extraction of relevant visual information amidst the noisy background is of critical importance for coordinating movement and avoiding collision with conspecifics. This study addresses two major facets of insect visual behavior: multiple target tracking and discrimination, during variable visual stimuli encounter. Experiments with walking desert locusts, *Schistocerca gregaria*, were performed in controlled conditions to understand the associated sensorimotor processes and decision-making. We investigated if a) locusts exhibit preferential response to selective stimulus when presented with multiple relevant stimuli simultaneously, and b) locusts respond differently to multiple copies of the same stimulus presented differently along different axes, orientations and speeds. Numerous visual stimuli including video clips of swarming locusts, random dot kinematograms and geometrical shapes with varying parameters were presented to tethered locusts walking on an air-cushioned trackball. High speed video recordings recorded the locusts' response by tracking the head pose, body angle and movement trajectory. In addition, neurophysiological responses from the neck connectives of locusts were monitored. Our results suggest that the desert locust does respond deferentially to selective stimulus when presented with multiple contradicting stimuli simultaneously. The pause duration between the walking bouts, known to be critical for swarm formation, varies with the complexity of stimuli and appears to be critical feature of decision-making in a visually rich environment.

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Meat ants cut more trail shortcuts when facing long detours

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Engineered paths increase efficiency and safety but also incur construction and maintenance costs, leading to a trade-off between investment and gain. Such a trade-off is faced by Australian meat ants, which create and maintain vegetation-free trails between nests and food sources, and thus their trails are expected to be constructed selectively. To test this, we placed an artificial obstacle consisting of 300 paper grass blades between a sucrose feeder and the colony, flanked by walls of either 10 or 80cm length. To exploit the feeder, ants could detour around the walls or take a direct route by traversing through the obstacle. We found that, when confronted with a long alternative detour, 75% of colonies removed more grass blades and ants were also 60% more likely to traverse the obstacle instead of detouring. An analysis of cut patterns revealed that ants did not cut randomly, but instead concentrated on creating a trail to the food source. Meat ants were thus able to collectively deploy their trail clearing efforts in a directed manner when detour costs were high, and rapidly established cleared trails to the food source by focussing on completing a vertically aligned trail which is then followed by the ants.

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Baboons unequally modulate their behavior to maintain group cohesion

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Animals must modulate their speed and coordinate their behavior to stay in contact with other members of their group. Due to differences in body size and locomotor capacity, some individuals may need to walk faster (or slower) than their preferred pace to allow groups to stay together. To test whether individuals modulate their speed to facilitate group cohesion, we simultaneously tracked members of a troop of olive baboons (*Papio anubis*) in Laikipia, Kenya with GPS collars and integrated accelerometers. We identified the footfalls of walking baboons and defined each group member's 'characteristic walking profile' based on the distribution of stride frequencies observed when walking alone. We then measured their stride frequency when walking as part of a group, finding that smaller baboons increased their stride frequency and showed larger deviation from their characteristic walking profile compared to larger baboons, which decreased their stride frequency during group movement. Smaller baboons had higher dynamic body acceleration, a measure that correlates with energy expenditure, than larger baboons. These results stress the importance of considering the role of movement capacity in shaping a species' movement ecology and illustrate an approach for accomplishing the effects of differences in movement capacity under socially and ecologically relevant field conditions. Together, our findings suggest that group movement imposes consensus costs which are borne disproportionately by smaller group members and highlight how individuals' decisions are constrained by the need to maintain cohesion.

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Social allocation maintains bond stability in a wild rock hyrax population

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The structure and dynamics of animal social networks affect ecological and evolutionary processes. Social networks impact pathogen and information transmission, as well as reproductive success and survival. However, little is known about how animals maintain stable social relationships with their conspecifics. Until recently social relationships could be described using only coarse measures, mostly based on human observation of social interactions. Here, we used proximity sensors to document 32,726 interactions in a wild rock hyrax population at 1Hz resolution. We found that most hyrax pairs maintained stable relationships of varying strengths over a couple of months. We analyzed a two-months period, and found that hyraxes employed social allocation on a daily basis to maintain bond stability. That is, in a given day, hyraxes interacted more with conspecifics for whom the cumulative interaction time was lagging the one predicted by their daily mean. This compensation mechanism suggests that hyraxes keep record of past interactions and actively correct their 'social path' to maintain their social relationships. Our study opens new directions regarding the adaptive value of social stability and the mechanisms that maintain it.

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Hidden floral signals used by bumblebee pollinators

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Pollinating insects use a variety of floral signals to identify more rewarding flowers in their environment. This learning of floral displays is critical for maximizing foraging success. Some floral signals are salient to humans, while others are hidden to humans without use of modern technology. Here recent work from the University of Bristol Bee Lab investigating two such signal modalities is presented. Insect pollinators have previously been shown to respond to differences in flower temperature between flower species. Similarly, elevated humidity generated by evening primroses has been shown to be used by hawkmoths to locate rewarding evening primrose flowers. However, floral humidity's occurrence and use by pollinators outside of this single hawkmoth-primrose pollination system is unclear. Recent advances in thermal imaging technology have allowed surveys that reveal floral temperature differs across the flower surface, creating a temperature pattern. Similarly, use of affordable humidity probes and new robotic tools reveals many flower species produce floral humidity. Using captive bumblebees and conditioning techniques we demonstrate bumblebees can learn to distinguish artificial flowers that differ in each of these traits in a way comparable to real flowers. The presence of these 'hidden' floral signals, and the capacity of at least bumblebees to respond to them in a foraging context, expands our understanding of the range of multimodal floral signals pollinators respond to and the foraging decisions pollinators may make when visiting floral displays.

Juvenile cleaner wrasses can learn socially about the consequences of cheating

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Social learning is often highlighted as an important driver of the evolution of human cooperation as it can facilitate the spread of cooperative behaviours and lead to large scale-cooperation and to the cultural evolution of behavioral traits. In contrast, evidence for the use of social learning by cooperating non-human animals is currently limited, and they are thought to mostly rely on individual learning or instinct alone. Here we show that juvenile bluestreak cleaner wrasses (*Labroides dimidiatus*) can learn socially about the consequences of cheating in cooperative interactions and adjust their strategic behavior accordingly. Observation of a conspecific adult interacting with model clients that flee when the cleaner 'cheats' by eating a preferred food item (which corresponds to cheating by eating mucus rather than ectoparasites in nature), caused the juvenile cleaners to eat more against their preference - a behavior that equates to increased cooperation in natural settings. Observation of an adult interacting with model clients that differ in their responses to such cheating, influenced the observers' subsequent partner choice, leading them to choose a partner that is less responsive to being cheated. These results suggest that juvenile cleaner fish can extract and use information from observing the outcomes of cleaning interactions, indicating an active role for social learning in the development of cooperative strategies in a non-human animal. Our results further show that client's responses to cheating have reputational effects: they modulate the subsequent behaviour of observing cleaners and can thus influence cooperation dynamics at a larger scale.

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Necessity creates opportunities for chimpanzee tool use

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While social transmission mechanisms of animal cultures are well studied, little is known about the origins of behavioural innovations, even in established tool-users such as chimpanzees. Previous work has suggested that wild chimpanzees are especially prone to engaging with tools during extended periods of low food availability and after long travel, supporting the hypothesis that cultural innovation is facilitated by necessity revealing opportunities. Here, we tested this hypothesis with a field experiment that directly compared subjects' immediate variation in measures of current energy balance with their interest in a novel foraging problem, liquid honey enclosed in an apparatus accessible by tool use. We found that the previous distance travelled directly predicted subjects' manipulations of both the apparatus and the tool, while previous feeding time was negatively correlated to manipulation time. We conclude that 'necessity' augments chimpanzees' likelihood of engaging with ecological 'opportunities', suggesting that both factors are scaffolding foraging innovation in this and potentially other species.

Male and female song: intra-sexual versus inter-sexual song learning by New Zealand Bellbirds

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Despite female song being an ancestral trait for songbirds, research has predominantly focused on species where only males sing. Here, we compare song of male and female New Zealand bellbirds, *Anthornis melanura*, across a meta-population with varying levels of connectedness via male and female dispersal. We measured song sharing between the sexes for six populations and found that although populations had little repertoire overlap, sharing of syllables by males and females within populations was between 10 22%. We asked: 1) do shared syllables reflect inter-sexual song learning? 2) is inter-sexual learning a result of syllable prevalence within male and female populations? 3) are shared syllables similar for different populations? and 4) do shared and unshared syllables have distinct acoustic characteristics? We found that chicks of both sexes learnt male and female syllables, but that attrition of opposite sex syllables, presumably through social reinforcement, resulted in significant sexual dimorphism of adult repertoires. We found no correlation between the prevalence of syllables and the likelihood that a syllable was shared, nor between the prevalence of male and female shared syllables. Shared and unshared syllables had similar acoustic properties and shared syllables differed between populations. We conclude that the sexual dimorphism found in bellbird song is likely the result of social interactions within social networks prior to breeding. This research leads the way for future work on modelling how male and female song cultures develop and how they spread via social interactions.

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Koe: web-based software to visualise, segment and classify acoustic units in animal vocalisations

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Vocal communication is fundamental to the behaviour of many animal species. Vocal information can be encoded in the types of acoustic units employed (repertoire) and their temporal arrangement (sequence structure). To study repertoire and sequence structure requires classification of acoustic units, but this is currently hindered by a lack of tools, especially for large and diverse datasets. Here I introduce Koe, an application for classifying and analysing animal vocalisations. Koe offers bulk-labelling of units via interactive ordination plots and unit tables, as well as visualisation and playback, segmentation, measurement, data filtering/exporting and new tools for analysing repertoire and sequence structure - in an integrated environment. I demonstrate Koe with a real-world case study of New Zealand bellbird *Anthornis melanura* songs from an archipelago metapopulation. Having classified 21,500 units in Koe, I compare population repertoires and sequence structure between sites and sexes. Koe is web-based (koe.io.ac.nz) and easy to use, making it ideal for collaboration, education and citizen science. By enabling large-scale, high-resolution classification and analysis of animal vocalisations, Koe expands the frontiers of bioacoustic research.

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The Role of Team Heterogeneity in the Dynamics of Human Conversational Turn-taking

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Social groups can benefit from collective intelligence, where group members achieve an outcome superior to that which they could achieve on their own. In human social groups, such as project teams, conversation is a primary behavior that mediates the sharing, promotion and aggregation of differing knowledge and perspectives. However, heterogeneity in team members' traits can lead to systematic differences in interaction patterns, and thus, the extent to which each individual influences the group outcome. Here we examine the role that variance in communication behaviors play in team conversation dynamics by developing a data-driven simulation model of conversational turn-taking behavior. Data on the start and end times of individual speaking turns were coded from continuous audio recordings of meetings for seven self-organized engineering teams (3 - 4 students each, 24 total) during two summer engineering design internships in 2016 and 2017. Results indicate Americans (n = 13), who were more likely to be perceived as team leaders, had significantly shorter inter-turn intervals and were significantly less likely to interrupt others compared to non-Americans (n = 7 Malawians, 4 Brazilians), while turn duration and likelihood of being interrupted did not differ. Additional analyses will explore the roles of language proficiency, personality, and topical experience. Results are informing the development of a simulation model of conversational turn-taking behavior that we will use to explore how varying levels of heterogeneity in communicative behaviors influences emergent properties of the communication network. This study will promote understanding, and prediction, of the collective properties of human conversation.

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Transgenerational transmission of predator-induced phenotypic plasticity during sexual reproduction in a cyprinid fish

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Transgenerational phenotypic plasticity is a mechanism by which organisms attempt to predict future environmental conditions so as to adaptively match their offspring's phenotypes to their environment. Predator-induced defenses, ranging from behavior to morphology, are a well-studied example of phenotypic plasticity where first attempts have been made to understand their transgenerational transmission. However, most of these studies focus on asexually reproducing organisms with short generation times, thus little is known about the transmission of such defenses during sexual reproduction, which adds another important layer of phenotypic variation to transgenerational plasticity. Here, we report the first results of a comprehensive study on transgenerational antipredator phenotypic plasticity in a sexually reproducing common prey cyprinid fish with allopaternal care, the fathead minnow *Pimephales promelas*. Predation risk was simulated by continuously exposing fish in split-clutch rearing designs to either conspecific alarm cues that are released across aquatic taxa upon injury by a predator, or a control water treatment. Afterwards, we set up breeding combinations allowing us to control for parental vs. offspring effects via environmental match/mismatch designs, paternal vs. maternal precopulatory effects, postcopulatory effects of parental care by parents from different environments and grandparental vs. parental effects. Over a 2-year period, we then assessed morphology, shoaling behavior and boldness in up to 4200 fish across 18 treatments during three generations. Our results may allow inferences about how environmental information is transmitted across generations and interacts with an individual's own perception of the environment as well as about the evolutionary consequences of transgenerational phenotypic plasticity.

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Species-specific strategies increase unpredictability of escape flight in eared moths

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Many prey animals form mixed-species groups, which provide various benefits ranging from increased food intake to increased chance of predator detection. The escape-tactic diversity hypothesis predicts another benefit. It postulates that the overall unpredictability of evasive movement is increased if multiple species with different evasive tactics mix, resulting in enhanced predator protection for the whole group. However, escape-tactic diversity could also be a functional consequence of morphological differences that correlate with evasive capabilities. Echolocating bats and eared moths are a textbook example of predator-prey interactions. Moths exhibit evasive flight with diverse tactics; however, the variability of their evasive flight within and between species has never been systematically quantified. In addition, moth species show variation in size, which correlates with their flight capability. We recorded flight strength during tethered flight of eight sympatric moth species in response to the same level of simulated bat predation. Our method allowed us to record kinematic parameters that are correlated with evasive flight in a controlled way to investigate species-specific differences in escape tactics. We show species-specific and size-independent differences in both overall flight strength and change of flight strength over time, confirming the escape-tactic diversity hypothesis for eared moths. Additionally, we show strong inter-individual differences in evasive flight within some species. This diversity in escape tactic between eared moths increases the overall unpredictability experienced by bat predators, likely providing better protection against predatory bats for the single individual.

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Should I change or should I go? How colour change and behavioural choices combine for camouflage

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Camouflage is driven by matching the visual environment, yet natural habitats are rarely uniform and comprise many backgrounds. Therefore, species often exhibit adaptive traits to maintain crypsis, including colour change and behavioural choice of substrates. However, previous work largely considered these solutions in isolation, whereas many species may use a combination of behaviour and appearance to facilitate concealment. Here we show that green and red chameleon prawns (*Hippolyte varians*) closely resemble their associated seaweed substrates to the vision of predatory fish, and that they can change colour to effectively match new backgrounds. Prawns also select colour-matching substrates when offered a choice. However, colour change occurs over weeks, consistent with seasonal changes in algal cover, whereas behavioural choice of matching substrates occurs in the short-term, facilitating matches within heterogeneous environments. We demonstrate how colour change and behaviour combine to facilitate camouflage against different substrates in environments varying spatially and temporally.

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Iridescence as Camouflage

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Iridescence is a striking form of animal coloration which is taxonomically widespread, but the adaptive function of iridescence is still poorly understood. Here, we will present new and unpublished data to show that biological iridescence, produced by multilayer cuticular reflectors in real jewel beetle (*Sternocera aequisignata*) wing cases, provides effective protection against predation by birds. Importantly, we also demonstrate that the most likely mechanism to explain this increase in survival is effective camouflage, and not some other protective coloration function, such as aposematism. In two separate field experiments using wild birds and humans as surrogate 'predators', we measured both the 'survival' and direct detectability of iridescent and non-iridescent beetle models, demonstrating that the iridescent treatment fared best in both experiments. We also demonstrated an overall effect of the specular reflection (glossiness) of the leaf background: an increased level of background specularity led to a decrease in both predation rates and direct detectability of targets. The latter suggests that iridescent prey can increase their chance of survival against visually hunting predators even further by choosing glossier backgrounds. Our study is the first to provide empirical evidence for the hypothesis that biological iridescence can work as a form of camouflage in a natural setting, thus providing an adaptive explanation for the taxonomically widespread occurrence of iridescence in prey.

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Movement behaviour demonstrates precocial abilities of African savannah elephant (*Loxodonta africana*) calves

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Cooperating with conspecifics has many benefits including predator protection and information sharing that can outweigh associated costs. Within groups, divergence in optimal behaviour can cause group fissions (separation) if the costs outweigh the benefits. African savannah elephants (*Loxodonta africana*) are nonsynchronous breeders that live in a matriarchal fission-fusion social structure meaning that herds can merge or split depending on the relative costs of group living. Despite this, little is known about how unsynchronised breeding, including a 22-month gestation period, parturition and the presence of a neonatal calf, affects movements and hence group fusion in African savannah elephants. Here, we examined the relationship between reproductive state and movement characterized using GPS tracking data collected during 20 births from multiparous elephants (≥ second calving). We analysed the data using three-state hidden Markov models to determine whether parturition results in a distinctive change in movement behaviour, characterized as hourly and daily speed, 95% minimum convex polygon (MCP) and sinuosity index. Overall, parturition had little impact on movement in multiparous females. Using linear mixed-effects models, we determined that speed increased and sinuosity index decreased during the ∼18 days after parturition, but, overall, movements before and after birth were not significantly different. Our results demonstrate the precocial abilities of elephant calves, which could be advantageous given both the matriarchal fission-fusion social structure of elephants and the mothers nutritional and water requirements. We speculate that, alongside cognitive development, elephants may have evolved an unusually long gestation period to facilitate an advanced stage of foetal physical development.

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Social hubs of an unsocial cat: cause and solution for the human-cheetah conflict

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Cheetahs naturally occur at low densities, which makes it unlikely for two individuals to meet by chance. With GPS data of >200 collared cheetahs (*Acinonyx jubatus*) we investigated their socio-spatial organisation. We detected a striking intraspecific communication network consisting of a regular pattern of communication hubs within the landscape. Each of these hubs was owned by territorial cheetah(s) which maintained numerous marking sites within the hubs. These marking sites were regularly visited by non-territorial males, which oscillated between two or three hubs, and irregularly by females. This spatial pattern was stable over consecutive cheetah generations. The is a unique system within mammalian species and offers exciting further research questions in understanding territoriality, mate choice, intraspecific communication and providing a key to mitigate human-cheetah conflicts. Namibia hosts one of the worldwide largest free-ranging cheetah populations. Most cheetahs roam on farmland where they come in conflict with livestock farmers. We showed that regular visitations of the communication hubs by various cheetah individuals created local 'hotspots' of cheetah density in these hubs and thereby increased the local predation risk for livestock animals. Shifting the cattle breeding herds away from these hotspots during the calving season drastically reduced losses. This is because cheetahs retained their spatial distribution pattern and preyed on naturally occurring prey species. Our approach of exploiting research insights of the socio-biology of conflict species to promote coexistence between humans and predators opens a promising area to develop solutions also in other conflict species with non-homogenous space use.

Long-term movements and home range changes: rapid territory shifts in meerkats

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Territoriality is a common space use pattern among animals whereby territories provide its inhabitants with important resources and can thus be associated with increased fitness. While the role of territory quality and changes of territory ownership have frequently been investigated, the changes of boundaries are less studied. We investigated space use changes in kalahari meerkats (*Suricatta suricatta*) and applied a novel analytical approach, based on calculating dissimilarity matrices based on the earth movers distance and periodic utilization distributions. We analyzed meerkat movements of 24 different groups distributed over a 16-year period. Groups had stable territories for several years before they abandoned their home range completely to move quickly to new areas where they again remained for several years. These shifts were often preceded by more frequent group interactions but did not seem to be a product of direct displacements by other groups. NDVI as a measure of food productivity and social factors such as dominance changes did not correlate to changes in territory boundary. Against our expectation space use changes were not accumulations of small changes, but instead, groups did long distance moves into unknown ranges. As groups can thus not profit from previous local knowledge, these moves likely have important fitness consequences on the group and population level.

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Foraging site selection from GPS telemetry in a marine foraging bat

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Habitat selection models can provide insight into how animals respond to their environment at multiple scales. Here we investigate GPS tracks of the Mexican fish-eating bat as it forages in the open ocean. The dynamic marine environment provides a challenge for animals attempting to reliably find prey as often the same location between nights will yield very different results. Our previous research found that bat foraging areas are on average several kilometers apart over consecutive nights, suggesting that bats cannot reliably predict prey location. Playback experiments and on-board audio recordings revealed that these bats rely on social information to find ephemeral prey patches, yet consistency in the direction of their foraging flights suggesting habitat selection at some level.

Here we ask if environmental variables measured by remote sensing are associated with foraging at two spatial scales, (nightly path, foraging patch) to identify predictors of habitat selection by fish-eating bats. We determined foraging locations through evaluation of behavioral segmentation methods with on-board audio recordings of buzzes. Using the best performing method, hidden Markov model, we parse tracks into foraging and commuting behavioral states and then use randomization tests to determine associations with environmental variables. Our results show that environmental variation fails to predict foraging patches, but at a larger scales bats choose to forage in areas with higher chlorophyll and steeper ocean slope, likely increasing the general presence of prey.

Habitat selection in a marine bat provides opportunities for comparison with other marine organisms foraging in the same unpredictable environment.

Do nonapeptides regulate parental care depending on experience in zebra finches?

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Recent research suggests that the nonapeptide neurohormones regulate parental behaviors in a diverse array of vertebrates. However, it remains unclear how these neurohormones regulate parental care among birds, especially those which exhibit biparental care, common across birds, or whether hormonal effects are contingent on a bird's previous experience as a parent. I measured the effects of nonapeptides on parental behaviors by injecting, over three treatment days, a short-acting oxytocin receptor antagonist (OTA) or a saline control into breeding pairs of zebra finches (*Taeniopygia guttata*) that either did or did not have previous parental experience. I then compared how the duration and/or frequency of parental behaviors changed over the five days of observation (including one day before and two days after injections were administered). To compare treatment effects on parental outcomes, I also measured chick growth and mortality rates for each pair. OTA and experience significantly affected the amount of time birds spent nest guarding, with inexperienced birds receiving the OTA increasing nest guarding relative to inexperienced controls or experienced OTA birds. Chicks reared by parents that received the OTA had significantly lower growth rates than chicks reared by control parents and, among experienced birds, higher mortality relative to control birds. Together, these results provide some support for the hypothesis that nonapeptides play a role in regulating parental outcomes and some parental behaviors in both experienced and inexperienced zebra finches.

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Parental provisioning behaviour and inheritance of social networks in a colonially-breeding bird

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Parental care period is costly for parents and offspring face various risks such as predation. Many bird species mitigate these costs by breeding colonially, with colonies consisting of many breeding individuals that generally tend totheir own nests. However, relatively little is known about how colonial species behave and care for their young after offspring have fledged the nest but remain dependent on their parents. This period often involves the formation of chick creches, and parents are thought to almost exclusively feed their own chicks mainly to maximise their investment. However, this creching period could also represent an opportunity for adults to feed potential extra-pair young or to provide social support to the offspring of their close associates. Thus, parents can foster their social environment and juveniles can gain the opportunity to form social bonds with unrelated and/or genetic parents. We explore these possible mechanisms using an automated monitoring system to identify and track the adults and offspring in replicated colonies of zebra finches. We find that adults feed both unrelated and related offspring. Long-term tracking, from the period of pair formation and through the reproductive season, allows us to link the care provisioning network to the adults' social networks. In doing so, we help revealing the process by which juveniles develop their own social network as they integrate into an existing social environment and identifying whether they inherit their parents' social networks.

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Postnatal care compensates for prenatal inequalities in wild banded mongooses

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In vertebrates prenatal conditions during gestation and postnatal care during development both have important, lifelong consequences for offspring health and survival. Where mothers raise their own young, variation in maternal condition is expected to amplify prenatal inequalities among offspring, because mothers in good condition can invest more in both prenatal and postnatal periods. However, in many animal societies postnatal care is provided by other group members, not just mothers. Where carers are uncertain about their relatedness to offspring, theory predicts they should direct care in a manner that levels offspring inequality in case the poorer quality offspring are closer kin. We tested this hypothesis by manipulating maternal condition in wild banded mongooses (*Mungos mungos*) where relatedness between adult carers and communal litters of pups is uncertain. We conducted a 3-year field experiment feeding half the females from the each breeding attempt, producing 50 pups from fed females and 50 pups from non-fed control females. Fed females produced heavier offspring and provided more postnatal care. As predicted, they targeted this extra care at the smaller, lighter offspring of control females, rather than their own offspring, so that by nutritional independence the initial differences in body mass between the offspring of fed and control mothers had been eliminated. Our study shows that postnatal care can compensate for prenatal inequalities in maternal condition. The evolution of such mechanisms may buffer societies which communally care for offspring from inequalities in maternal condition and could weaken transgenerational effects on offspring fitness.

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Ontogeny of foraging via assisted learning by mothers in Egyptian fruit bat pups

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The transfer of information between parents and offspring is particularly important in mammals with relatively long periods of offspring dependency, such as fruit-bats. Offspring might learn several important skills during this period, especially how to and what to forage. Previous findings in non-bat species have revealed that juveniles learn a significant amount of what they know about foraging through social learning. Numerous bat species have been observed carrying non-volant young in flight, while both foraging and roost switching. This behavior is likely costly for mothers, and it is the benefits for the offspring that are still not fully clear. In this study, the developmental process from non-volant to independently foraging pups was monitored using high resolution GPS and telemetry tracking. Successful tracking of over 35 mom-pup pairs provides the first evidence of assisted learning of foraging by Egyptian-fruit-bat mothers. This process includes five distinct stages: (1) Pups are attached to their mothers 24/7 (2) Gradual-detachment: Mothers carry pups for shorter bouts, drop-off pups on a tree, forage alone, then pick-up pups on their way back to the cave (3) Pups are left alone in the cave (4) Pups fly independently to known sites, where their mothers previously dropped them off (5) Pups expand foraging to new sites unique to them. Our data shows that mother bats actively mediate learning of independent foraging by repeatedly placing pups on trees, which they then visit on their first foraging bouts.

Collective decision making in fish schools

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Decision making, perception, and cognition are concepts that have been thoroughly studied in neuroscience. However, these processes are not restricted to the brain of a single animal. Through collective information processing, groups of animals exhibit responses to their surroundings that require information that exceeds the perceptive capacity of any individual. In order to study collective information processing, we have adapted strategies for studying perceptual decision-making from neuroscience to animal collectives. By presenting visual stimuli to schools of fish ranging in size from 8 to 1024, and tracking their movement with computer vision, we were able to quantify and investigate collective decisions of varied difficulty. We observed and quantified emergent properties of collective responses, and found that the accuracy and dynamics of collective processing scale with group size. We identified characteristics of collective responses that are analogous to processes observed in the brain, including evidence accumulation and working memory. Through comparison with other distributed information processors (such as neuronal networks), we aim to explore the use of animal collectives as a system to study self-organizing network processors.

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Context-dependent decision-making in house sparrows

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Adaptive foraging decisions depend on choosing food-related cues associated with high value of reward, as well as on recognizing or classifying such cues correctly. However, the relative weight that should be given to expected value versus the likelihood of correct recognition may differ across contexts. In a set of experiments, we examined how reward visibility and accessibility affect the relative weight house sparrows give to two parameters - the expected net value associated with a cue and the similarity of this cue (or its contextual setting) to those experienced in the past. The results suggest that sparrows considered both contextual similarity and net-value in their foraging decisions but gave them different weights based on reward visibility and accessibility: When rewards were visible and easily accessible the sparrows showed no preference for neither of the cues. When rewards were visible but reaching them required considerable handling time, the sparrows preferred color cues previously associated with shorter handling time (i.e. higher perceived net value) over cues presented in a context similar to that experienced during training. Finally, when the rewards were hidden, sparrows preferred the cue presented in a context similar to that experienced during training. Thus, sparrows seem to dynamically adjust the weight given to previously learned cues according to current context, relying on cues that increase the chances of finding food when it is hidden and on cues that were associated with handling it more efficiently when it is exposed.

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Heritable variation in cognitive traits in a semi-natural system, the pheasant

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In order to understand the evolution of cognitive abilities, which underpin behaviours critical to an individual's fitness, we need to understand both how selection acts upon them and their patterns of heritability. Recent work has started to explore the fitness consequences for free-living individuals with particular cognitive abilities. However, our current understanding of the heritability of these abilities is predominantly restricted to domesticated species (poultry, rodents, model lab species) that have been subjected to artificial selection and these studies generally only look at the heritability of single cognitive abilities. We investigated the heritability, as well as their covariation of four cognitive abilities: inhibitory control, visual and spatial discrimination, and spatial learning ability in four generations of > 450 pheasants. Pheasants were reared in captivity but bred from adults that have lived and survived natural hazards for at least a year in the wild. Hence, they have been subject to selection on survival. Pheasant chicks are precocial and can be reared without parents, enabling us to standardise environmental effects during early life and remove effects of parental care. We constructed a pedigree for our birds and used animal models to account for genetic and environmental contributions to heritability. We found that performances on the different cognitive tasks varied in their genetic contributions, from moderate to no heritable component. We discuss possible mechanisms that may constrain or enhance the evolution of cognitive traits and discuss these findings in terms of modular models of the structure of animal cognition.

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Relationship between population densities, forebrain measurements and social competence in cleaner fish

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Several “intelligence” hypotheses attempt to unravel the links between ecology, cognitive abilities and brain neuroanatomical traits, but tests based on comparative research remain contentious. To reduce the effects of potentially confounding variables, it has been proposed to study the effects of naturally occurring variation in the ecology of a species on brain features. Here, we show that in a wild fish species, the mutualistic cleaner wrasse *Labroides dimidiatus*, abundance of individuals as a proxy for social complexity in natural habitats correlates positively with the relative cell counts in the cleaner forebrain. Furthermore, forebrain relative size increased with the increase in the social complexity but only in the brains of individuals with high cognitive performance. Thus, within a species, a measure of cleaner abundance, as a proxy for both intra- and interspecific social complexity, correlated with forebrain complexity as a function of cognitive performance. The results thus provide evidence for the hypothesis that social challenges and their solution promote an increase in brain complexity.

Social behavior and disease transmission

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Although group-living may increase the overall fitness of individuals, it also facilitates the transmission of infectious diseases. Understanding the impact of population size, density, social interactions and environmental complexity on transmission is critical for being able to predict epidemic spread under novel conditions. We use the carpenter ant *Camponotus pennsylvanicus* to study the spread and transmission of a GFP-(green fluorescent protein)-labeled generalist pathogen (*Metarhizium robertsii*) as model system. Using modern microscopy and tracking of individual ant movement based on deep-learning algorithms allows us to study disease dynamics in complex scenarios. We will present empirical data on ant movement, proximity networks, pathogen distribution and transmission collected from 48 ant nests.

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Being flexible in a rigid trait: modulation of Lévy walks in termite workers under distinct social encounter context

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Movement is a crucial element of behaviour: animals displace themselves in space in search of suitable conditions for survival and reproduction. It is hence expected that movement patterns in animals will be determined by the way they efficiently balance (i) their intrinsic individual displacing abilities with (ii) the spatial distribution of food, enemies, mates, etc. However intuitive, this notion needs better evidence, as it lies in the core of the still unsolved mechanisms generating search strategies in animals. That these searches are typically described as a Lévy walk process is consensual, though.

Here we explore such a balance in the context of social interactions among termites. We checked whether changes in the density of nestmates and the density of castes would trigger search-modulation in termite workers of *Cornitermes cumulans* when searching for social interactions. Our results seem to point to a two-fold process. Termite workers confined in petri dishes do displace them- selves in a Lévy-like walking, no matter the density or the type of targets therein present (targets being other workers or soldiers, which do differ in interactivity). Such movements, however, seem fine-tuned by group composition: as the density of workers increases so does the μ exponent of the power law describing the frequency of their step lengths.

In contrast, the mean speed of focal termites decreased exponentially with the increments of both the density of nestmates and the density of termite workers. Whereas indicative of interindividual movement obstruction, these results also point out that such an obstruction is affected by the type of interaction (worker-worker or worker-soldier). It is hence plausible to suspect that their general Lévy displacement pattern would indeed be affected by social interactions more than simply by the obstruction effect of inert targets.

It seems, therefore, that (i) while termites do have an innate propensity to perform Lévy walks, (ii) external constraints, at least in the form of opportunities for social interactions, would add an important modifier to these displacements.

Parasite-induced bioluminescence deters predation of infected hosts by nocturnal rodent predators

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Anti-predator defences are ubiquitous in nature with aposematism a common and well-studied example. Aposematism normally combines a repellent defence, such as a toxin with a warning signal, usually visual, olfactory or acoustic. There is increasing evidence that bioluminescence can act as an aposematic signal to deter predation of prey that have chemical defences. We examine a novel example of such signalling; the bioluminescence of infected insect cadavers that is induced during infection by the parasitic nematode *Heterorhabditis bacteriophora* and its symbiotic bacterium *Photorhabdus luminescens*. This nematode-bacterium complex infects and kills soil-dwelling hosts within which it reproduces for around two weeks before new infective nematodes emerge. During this incubation period the insect cadaver, and the reproducing nematode-bacterium complex, is susceptible to predation, which is fatal for the developing parasites. We hypothesise that bioluminescence in this system acts as a warning signal to deter predation of infected hosts by nocturnally active, foraging predators. Using non-invasive CCTV monitoring, we tested both olfactory and bioluminescent deterrents by assessing the behavioural responses of house mice (*Mus musculus*) towards infected or uninfected insect prey. IVIS Spectrum In Vivo Imaging system was specifically used to evaluate bioluminescence signals under different light conditions. Mice did not respond to the olfactory cue but did spend less time near bioluminescent prey, indicating an avoidance of prey based on a luminescent signal. Bacterial symbionts in this system may have evolved exaggerated luminescent signals in order to protect a parasitic colony from predation.

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Parasite infection affects individual and thereby collective movements of three-spined sticklebacks

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Parasitism is ubiquitous in the animal kingdom. While many fundamental aspects of host-parasite relationships have already been unravelled, few studies have systematically investigated the effects of parasites on organismal movement. Focusing on the stickleback - *S. solidus* model system, here we combine detailed behavioural experiments with agent-based model simulations to get a mechanistic understanding of how parasitism can drive individual and collective movement dynamics. By individual-based tracking of fish with different levels of infection, we found that parasitized individuals swam slower, accelerated slower, and turned slower than healthy fish, and were more predictable in their movements. These effects were stronger the higher the parasite load of the fish, and were consistent across different solitary and social contexts that affected the average movement patterns of the fish. In turn, pairs composed of two parasitized individuals were not only slower, but also less cohesive, less aligned, and less coordinated than healthy pairs, with mixed pairs showing intermediate levels of behaviour. Furthermore, in such pairs, healthy fish were much more likely to lead their parasitized partner, and increasingly so the higher its parasite load. These social patterns emerged naturally in model simulations of self-organised groups composed of individuals with differences in speed and turning ability. Together, these results show how *S. solidus* parasite infection impacts both the motivation and capacity of individuals to move and how this in turn affects collective patterns without the need for active parasite manipulation, providing new mechanistic insights into the effects of parasitism on host movement dynamics.

Soldiers, workers and their moves: group structure and collective motion in termite societies

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Coordination is fundamental for large-scale animal groups on the move. When foraging, termite societies coordinate movement by establishing a series of interconnected pathways, thus facilitating navigation through complex environments. Several studies have elucidated the chemical ecology behind the formation of such trails, but little is known about behavioural mechanisms modulating the patterns. In this research, we developed an empirical framework to investigate the underlying mechanisms of coordinated collective motion in termite societies. Specifically, to test how group structure affects collective patterns, we evaluate both the emergence and maintenance of self-organised trails in different caste-ratio configurations. Using high-resolution videos and image-based tracking technologies, we detect trajectories and extract posture data for individuals over time. By performing quantitative analysis of movement, we gather information about the spatiotemporal dynamics, allowing comparisons of performance between groups in different scenarios. Our results provide evidence that the singularity of each termite caste goes beyond their innate morphological differences. The behavioural patterns observed for soldiers and workers indicates that the rules governing the collective motion of each group are unique. This means that workers and soldiers should not be interpreted as equal contributors in shaping collective patterns. Still, although castes operate in different ways, we reveal phase transitions in the behavioural response and an optimal caste-ratio configuration in which consistent coordination is more likely to emerge. We argue that mechanisms of coordinated motion in termites have been shaped under specific selective pressures, not necessarily those acting in Hymenoptera, as often assumed or suggested in the past.

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How ant-to-ant feeding interactions lead to colony-level regulation of food-intake rate

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Ant colonies send only a small fraction of their workers to do the foraging. Upon finding a source of liquid food, these foragers perform repeated bouts of filling their crop (their 'social stomach') at the food source, and unloading it in local mouth-to-mouth interactions to recipient ants in the nest. In this decentralized system, how can it be assured that the food brought in by the foragers matches the needs of the bulk of the colony? By imaging the real-time flow of fluorescent food in a colony of individually barcoded ants, we quantitatively describe an emergent colony-level regulation: the total rate of food flow into the colony is proportional to the colony's total level of hunger. This relationship is mediated by the amounts of food passed in local interactions, which are governed non-trivially by the food loads of the recipients. Additionally, on average, the frequency of trips of a single forager are also proportional to the colony's level of hunger. By analyzing the foragers' exits from the nest as outcomes of a Markovian decision process, we gain insight to the local factors that may translate colony hunger into individual foraging frequencies. Our findings suggest that the observed colony-level regulation may emerge without the need for individual foragers to actively assess the state of their colony.

Multimodal navigation in ants: How do different strategies interact?

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Ants have long been a model organism for the study of navigation, due to their robust and impressive natural foraging performance. Effective navigation is a multimodal process taking into account information from different sources tuned to the sensory ecology of a navigator. For ants, the combination of innate navigational strategies and the learning of environmental information is a key to their success, with the main innate strategy being Path Integration (PI). We recorded ants being guided by PI and found that (i) ants' walking speed decreases significantly along homing paths and stays low during subsequent search paths and (ii) ants are influenced more strongly by novel or learnt visual cues the further along their homing path they are. These results suggest that PI modulates speed along the homing path in a way that might help ants search for, utilise or learn environmental information at important locations. Ants walk more slowly and sinuously when encountering novel or altered visual cues and occasionally stop and scan the world, this might indicate the re-learning of visual information. We also investigated how two learned sensory modalities interact by looking at visual and olfactory guidance in navigating ants. We see that multiple cues lead to more accurate and efficient ants, but with more complex paths. Moreover, if olfactory and visual cues are learnt together, both of the cues are necessary for successful navigation. However, this binding seems to depend on the 'usefulness' of the available cues.

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Using automated tracking to show how honey bees move within their nest

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The ecological dominance of the social insects is due in part to how colonies allocate tasks between individuals. In honey bees, age polyethism regulates task allocation, with tasks being performed in well-defined areas of the nest. It is unknown, however, how movement patterns within the nest get workers to the appropriate location at the appropriate age. To address these questions, we require methods that cover spatial and temporal scales at both the level of the individual bee, and the whole colony. This requires continuous tracking of multiple individuals, which fortunately has become possible with recent advances in automated tracking software. In collaboration with the Landgraf Lab and their BeesBook tracking system, we tracked honey bees throughout their lives, and their changing nest environment. Using analysis techniques from movement ecology, but scaled down to the nest environment, we show how workers change their use of different nest areas as they age, and how these techniques can be used to back-calculate task allocation among workers. Unlike multicellular organisms, whose units are mostly fixed to a location, a honey bee colony is comprised of movable units that interact with each other and with their nest environment. The focus of this research is to understand how movement patterns generate a superorganism whose subunits interact as a collective.

Whistleblower: Variability of call combinations in a cooperatively breeding primate

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The great variation in vocal complexity across the animal kingdom is proposed to be associated with aspects of sociality, such as group size and breeding system. Analyses of such relations rely on properly assessing vocal complexity, which not only incorporates the vocal repertoire. We hence investigated complexity of call combinations in a cooperatively breeding primate species: Common marmosets (*Callithrix jacchus*), which form comparatively intermediate to small groups and are highly vocally active. Previous studies described 13 to 20 adult call types occurring singly, in series and combinations. We recorded vocalisations of five wild groups across different contexts in their natural environment and thus captured most variation in adult call types and combinations. We focussed on combinations with long-distance, whistle-like phee calls emitted by the dominant pair. This call type was given singly, in series and in 68 different combinations with nine different call types and two to seven calls per combination. Context analyses so far did not reveal significant differences between selected call combinations (preliminary results), yet our study revealed highly variable and intermediate call types that did not fit into previously described categories. The variability in call types and combinations is thus much higher than previously thought and demands new methods to characterise the vocal repertoire, assess vocal complexity and clarify the meaning of call types, combinations and modifications. Such variability in vocalisations provides the scope for complex information transfer and adds to the evidence that vocal complexity of cooperatively breeding primates rivals that of non-human great apes.

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Do Starlings use 'contact calls' to coordinate group foraging behaviour?

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Many group-living animals travel together and are thought to use calls to coordinate group movement. 'Contact calls' are a category of calls that are thought to be important in this group coordination. However, while very common across many taxa, how 'contact calls' function has not been especially well studied. While some experiments have addressed how individuals or groups use contact calls, how individuals use and respond to calls to influence the group itself remains unknown. Starlings are a social species thought to use 'contact calls' extensively to coordinate group movement and therefore provide a useful species to investigate group movement coordination. To determine how these birds use 'contact calls' to coordinate group movement, we, first, examined group movement events to determine how calls are used to coordinate group movement to and from food resources. Next, we explored the social context of these calls. We used both 3D visual and acoustic localization technology to determine both who instigates and responds to movement events, and who vocalizes during these events. By tracing who calls, when, and from where, we can determine both how these calls serve to coordinate group movement and who drives this behaviour.

Experience of the signaller explains the use of social versus personal information in the context of sentinel behaviour in meerkats

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To maximise foraging opportunities while simultaneously avoiding predation, group-living animals can obtain personal information on food availability and predation risk and/or rely on social information provided by group members. Although mainly associated with low costs of information acquisition, social information has the potential to be irrelevant or inaccurate. In this study we use playbacks of individually distinct sentinel calming calls produced during sentinel behaviour, a form of coordinated vigilance behaviour, to show that meerkats (*Suricata suricatta*) discriminate between social information provided by different sentinels and adjust their personal vigilance behaviour according to the individual that is played back. We found that foraging group members acquired the lowest amounts of personal information when hearing social information provided by experienced individuals that act as sentinels most often in their group. Our study shows that social information can be flexibly used in the context of sentinel behaviour in order to optimize the trade-off between foraging and vigilance behaviours dependent on discrimination among signallers. We also provide novel evidence that the experience of sentinels rather than their age or dominance status is the main factor affecting the extent to which individuals use social information.

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Female song repertoires in the New Zealand bellbird: sexual and temporal variation

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How song repertoires vary between species and change over time is well studied in male songbirds. However, female song is much more common and widespread than once assumed, making it timely for more research on how female song repertoires compare to male counterparts, especially in species where females have complex song. We investigated the syllable repertoire of the New Zealand bellbird (*Anthornis melanura*), a species where both sexes have complex but sexually dimorphic song. Songs were recorded at the individual and population level to assess syllable repertoire size and temporal variation. Overall, 96 syllable types were detected in the population over four recording years, of which 58% were unique to males, 32.3% unique to females and 9% were shared between the sexes. Individual syllable repertoire sizes ranged from 15 to 32 (n = 7) syllables for males and 6 to 15 (n = 6) syllables for females. The population syllable repertoire of both sexes changed across years at a similar rate based on Jaccard's similarity coefficient (female 52.6-67.9%; male 58.6-73.7%). For males and females, certain syllable types also appeared to vary in their prevalence in the population across the years. The individual variation found suggests both sexes may be influenced by potential phenotypic or condition-based factors that can influence song repertoires. The sexes' syllable repertoires changing over time at a similar rate also suggests selection pressures may be acting on both sexes for an analogous function of their song.

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Multimodal communication in wild primates: comparing sociality and multimodal communication in two lemur species

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Animals exhibit an astonishing diversity of communicative systems, with substantial variation in both the nature and the number of signals they produce. Variation in communicative complexity has been conceptually and empirically attributed to social complexity. The 'social complexity hypothesis for communicative complexity' (SCHCC) suggests that animals living in more complex social environments exhibit more signals and/or more complex signals than animals living in simpler social environments. Much research in the context of the SCHCC has focused on a single modality, whereas several good reasons exist for acknowledging the multimodal nature of both signals and communicative systems in this framework. First, multimodal signals are by definition complex because they involve more than one signalling and perceptive system. Second, the flexible use of different modalities in multimodal signals permits another level of complexity embedded in multimodal signalling. At the system level, focusing on one modality may lead to over- or underestimation of the relationship between social and communicative complexity. Using such a comprehensive approach, we compared the communicative systems of two closely-related species of *Eulemur* with similar morphology and habitats, but different social systems. We studied 33 wild *E. rufifrons* (5 groups) and 10 wild *E. mongoz* (3 groups) in Madagascar. Based on 449 hours of focal behavioural observations and 284 hours of recordings, we compared their social and communicative complexity. We established a cross-modal signal repertoire to contribute to a more comprehensive assessment of communicative complexity, and to allow for more meaningful tests of the SCHCC.

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Morphogenesis of networks in polydomous ants

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Many biological systems are dependent on transportation networks for the efficient distribution of resources and information. Network builders face the challenge of balancing conflicting network properties such as robustness, efficiency and costs. Polydomous ant colonies are split between multiple spatially separated nests. They build and maintain physical trails that connect their nests to each other and to food resources. The resulting transportation network is used to distribute workers, brood, and food. The morphogenesis of these complex networks and in particular the individual mechanisms underlying them have not yet been quantified. There is empirical evidence that networks are organised at the local level between neighbouring nests and not at the colony level. We test this hypothesis in the species *Formica lugubris* with a model developed at the scale of the colony. The model consists of simple rules of interactions between nests based mainly on distance metrics. The model is validated against empirical data collected for 7 years on 9 colony networks in England. We find a good agreement between simulated and empirical data on many emergent quantities such as the number of trails per nests and centrality measures. We infer the mechanisms possibly involved at the scale of the individuals, with a focus on the diffusive behaviour of motion of scouts. This work provides for the first time a model of morphogenesis of networks in polydomous ants quantitatively validated against empirical data and will be the basis of the development of a unifying theory of dynamic transport networks across biological systems.

Dynamic ant networks: how does social structure respond to changes in the resource environment?

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Animal social structure is shaped by environmental conditions, such as food availability; this means that changing conditions can alter social structures and result in cascading ecological effects. Understanding both how the resource environment causes certain social structures to arise, and also how resilient such structures are in the face of environmental change, is essential to understand the relationship between animal societies and their ecological context. Wood ants are an ideal study system for this, because they depend on discrete identifiable food resources (trees), and form large networks enabling resource sharing between socially connected nests of the same colony. We have collected data on the social network dynamics of 13 large multi-nest colonies of the wood ant *Formica lugubris* over 7 years, and manipulated resources to test social resilience. Our dynamic network analysis results show that nest survival is affected by social position; specifically, the flow of resources through a nest, a result of its position within the wider network, determines a nest's likelihood of surviving. Combined with size-based nest foundation, this enables the network as a whole to track the resource environment, resulting in a network structure that is well-matched to the spatial pattern of resources. Using manipulations to prevent access to certain key resources, we show that losing an important food source causes colony networks to split into smaller components, but without reducing growth or survival. Taken together, these results show a dynamic social structure that responds flexibly to both gradual and abrupt changes in the resource environment.

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The distributed regulation of multiple nutrients in ant colonies

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Nutritional regulation by ants is an intriguing process in which food collected by a small fraction of workers, and then distributed among the rest, satisfies the distinct nutritional requirements of the entire colony. It was previously shown that ants can regulate their protein and carbohydrate intake at both the collective and individual levels. This control is especially impressive considering that information about the global supply and demand is not available to any single individual. Here we present, for the first time, preliminary results on multi-nutrient dynamics in ant colonies using a two-color fluorescent imaging setup. Colonies of individually barcoded ants were presented with two food sources, each containing a different protein:carbohydrates ratio (P:C) and a distinct fluorescent color. We tracked the nutritional state of the colony throughout time until the P:C intake target was reached. On the individual level, we directly examined the behavior of the forager ants and their decision-making at the food source in relation to the colony's nutritional state. This information can shed light on how colony-level regulation emerges from individual behavior.

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Multi-level structure in feral horse society: Evidence from the aerial observation from drones

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Some mammalian species of different taxonomic groups, including humans, have developed social structures with nested levels of organization. This multilevel society is one of the most complex social systems in animals, but their function and evolutional process are still poorly understood especially for non-primate species because it requires good observation of large numbers of identified individuals. Equine groups are one of the taxa that have nested social structure, and there are some studies on several species such as plains zebras and Przewalski's horses, but not on domestic horses (*Equus caballus*). Studying the inter-group relationships of feral horses and comparing those of the other equine species may help understanding their origin and their ecological and social meanings. In this study, we aimed to reveal whether domestic horses form multilevel societies. We took aerial photos of feral horse herds in Serra D'Arga Portugal in 30 minutes interval using drones, identified all the individuals and collected their position data. In the field, we observed 21 harems, 2 bachelor groups and several solitary bachelors. Their home range were largely overlapped and the area of convex hull of these groups were significantly smaller than each home range, which suggests harems and bachelors aggregates to form a herd. Moreover, this herd had a structure that large harems were likely to be in the center, while bachelors were in the peripheral zone, and small harems were located somewhere between that. The presence of this stable spatial pattern strongly indicates the multilevel structures of feral horse society.

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Within-group variation and synchronization in nocturnal activity of free-ranging olive baboons

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Despite decades of detailed behavioral data collection on diurnal primates, we still know exceedingly little about what these animals do during the night. Assessing the behavior of primates during their most vulnerable hours is critical to our understanding of their behavioral ecology. We fit over 80% of the adults and subadults in a group of free-ranging olive baboons with collars bearing GPS and triaxial accelerometer units, and collected high-resolution bursts of accelerometry data once every minute overnight. We applied a machine learning classifier to determine when each baboon was in motion, indicating that it was active, or was sedentary, indicating that it was resting or sleeping. We quantified the amount of nocturnal activity in the baboons and evaluated the individual consistency and within-group variation in the amount of rest they experienced overnight. We then used permutation tests to assess synchronization between groupmates in their nocturnal activity patterns and investigated the underlying reasons for synchrony. Our results indicate that baboons are active quite frequently during the night, suggesting nocturnal vigilance as a potential antipredator strategy. We also found substantial variation between groupmates in their nocturnal restlessness. Given the importance of sleep to health and cognition, this result suggests that variation in sleep quality could contribute to within-group variation in fitness. We also discovered that baboons often synchronize their bouts of nighttime activity with their groupmates. The time that baboons allocate to maintaining their social relationships might therefore not be limited to daylight hours.

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The ManyPrimates Project: Establishing an infrastructure for collaboration in primate cognition research

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Tracing back the evolutionary history of cognitive abilities requires large and diverse samples. Particularly in primatology, such samples are usually beyond the reach of individual researchers or institutions. Therefore, studies are often limited to small numbers of individuals and species, which prevents researchers from answering questions regarding the structure of individual and species differences in cognitive abilities. The ManyPrimates project was created to address these questions by providing a large-scale collaborative framework for comparative studies in primate cognition. Here we present data from a pre-registered pilot study on short-term memory. In this delayed-response task, individuals could access food rewards by remembering under which of three opaque cups the reward was hidden after a 0, 15, or 30-second delay. We tested 176 individuals from 12 primate species housed at 11 sites. Overall, individuals performed better with shorter delays, in line with previous research. A phylogenetic analysis revealed a strong phylogenetic signal for short-term memory abilities even though, with only 12 species, the validity of this analysis is limited. Our initial results demonstrate the feasibility of a large, collaborative open-science project in primate cognition research. In the future, the ManyPrimates project will provide the opportunity to address long-standing questions in primate cognition and behavior with large and diverse datasets.

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Do capuchin monkeys show strategic information seeking to fill gaps in their knowledge?

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Previous research found that capuchin monkeys (*Sapajus apella*) seek information about the location of food (Marsh MacDonald, 2012). In chimpanzees (*Pan troglodytes*) searching extends to functional tools which can be used to obtain food (Bohn et al., 2017). However seeking functional information is yet to be shown in monkeys. We presented 12 capuchin monkeys with a novel information seeking task where information could be sought from two locations; looking below a barrier provided information about a cups contents, looking above a barrier provided information about a cups functionality (open or sealed). Cups were presented in three configurations; all baited (all cups were baited but only one was open), all open (all cups were open but only one was baited), and mixed (two cups were baited and two were open, but only one was open and baited). Initially monkeys were trained to select open-baited cups when all information was visible. Then a barrier occluded the cups so individuals had to search before choosing in order to make an informed decision. Searching was more likely once information was occluded (LRT: χ^2=17.95, df=2, p<0.001). However search location was not significantly affected by cup configuration (above search LRT: χ^2=0.832, df=3, p=0.841; below search LRT: χ^2=2.565, df=3, p=0.464). This supports previous findings that capuchins will search for information to fill gaps in their knowledge. However we found no evidence that searching was sensitive to which piece of information was required. We conclude that capuchin monkeys show selective but not strategic information searching.

Green monkey responses to drones: insights into the evolution of alarm call systems

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One of the core facets of the human language faculty is the ability to designate objects and events in the environment. A prerequisite for conventionalized communication in the auditory-vocal domain is flexibility in both vocal production and comprehension of sounds. To evaluate the flexibility in vocal production and comprehension in a nonhuman primate species, we presented a novel aerial threat, namely a drone to West African green monkeys, *Chlorocebus sabaeus*. Calls given in response to the drone were clearly distinct from alarm calls given to other potential predators, but highly similar to those given by East African vervet monkeys, *C. pygerythrus*, to eagles. An analysis of > 3000 calls revealed that the alarm call repertoires of both species were structurally highly similar, although the green monkeys' call types were overall less distinct. To probe how rapidly the animals attached meaning to the sound of the drone, we conducted playback experiments after 1-3 exposures to the drone. Subjects immediately responded with orienting responses, including scanning of the sky and running into cover. In conclusion, the structure of the alarm calls in this genus is highly conserved, while comprehension learning is rapid and open-ended. Our findings support the view of a deep dichotomy in the flexibility in vocal production vs. auditory learning in terrestrial mammals; this dichotomy has also been found in other species, such as domestic dogs and suggests that in this clade, flexibility in the auditory domain evolved prior to the flexibility in vocal production.

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Using thermography to understand third-party social evaluation in cooperatively breeding common marmosets

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Third-party social evaluation is crucial for group living species to navigate social networks and to keep track of potential cooperation partners. Experiments with human actors have shown that marmosets are able to evaluate social interactions between humans but experimental evidence of social evaluation of conspecifics is lacking. Additionally, behavioral reactions during social evaluation can be very subtle and not all social evaluation necessarily leads to punishment or reward of these conspecifics. Measuring body surface temperatures with infrared thermography has recently gained importance as a non-invasive measure for emotional reactions. In particular, nasal temperature changes indicate changes in arousal. We assed marmosets' (n = 21) changes in arousal during playbacks of opposite sex outgroup individuals. We used two different types of playback-stimuli either simulating (1) a social interaction between an adult and an immature (interaction playback), which could be positive (combination of begging calls of the immature followed by food calls of the adult) or a negative (begging calls followed by antagonistic chatter calls), or (2) a single individual being present (non-interaction control playback) by playbacks of food, chatter or begging vocalizations. Our results suggest that marmosets' changes in emotional arousal differ after having witnessed the interaction vs. the control playback. Importantly, the reactions to the interaction playbacks cannot be explained as an additive effect of reactions to the control playbacks, indicating an understanding of the call combination. We validate the thermal reactions with simultaneously collected behavioral data and argue that thermography is more sensitive measure of arousal marmosets.

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HSP90 increases individual behavioural consistency in the desert locust

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All organisms can tailor their phenotype to changing environmental conditions whilst remaining robust to environmental perturbations. Heat shock protein 90 (HSP90) has been proposed as a key mediator of this robustness. HSP90 canalises intracellular machinery in yeast and morphological traits in animals and plants. HSP90 may have a role in synaptic function, but its role in regulating behaviour is almost entirely unexplored.

We investigated the role of HSP90 in behavioural consistency in the desert locust, *Schistocerca gregaria*, a species which shows extreme phenotypic plasticity. In response to crowding or isolation, locusts transform between a cryptic 'solitarious phase' that avoids other locusts and a brightly coloured and highly mobile 'gregarious phase' that is attracted to conspecifics.

We analysed the effect of pharmacological inhibition of HSP90 in a simple locomotor hesitation assay that measures the time a hungry locust takes to walk upwind across a beam towards a food odour. Locusts were starved and assayed twice daily for 4 days after daily injection with the selective HSP90 inhibitor 17-AAG or a vehicle control. The eight repeat observations per individual permitted Bayesian estimation of both between- and within-individual variability.

Solitarious locusts showed considerably greater between- and within-individual variability in locomotor hesitation than gregarious locusts. Inhibition of HSP90 had no effect on mean crossing time in either phase, but caused a clear increase in within-individual variance in both phases. It did not affect between-individual variance. Our data provide the first evidence that HSP90 canalises behaviour towards greater individual consistency.

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Identity domains in complex behavior: Toward a biology of personality

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Personality traits offer considerable insight into the biological basis of individual differences. However, existing approaches toward understanding personality across species rely on subjective criteria and limited sets of behavioral readouts, resulting in noisy and often inconsistent outcomes. Here, we introduce a mathematical framework for studying individual differences along dimensions with maximum consistency and discriminative power. We validate this framework in mice, using data from a system for high-throughput longitudinal monitoring of group-housed mice that yields a variety of readouts from all across an individual's behavioral repertoire. We describe a set of stable traits that capture variability in behavior and gene expression in the brain, allowing for better informed mechanistic investigations into the biology of individual differences.

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Personality-dependent movement, space use and fitness in wild house mice

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The causes and consequences of consistent individual differences in behaviour, called animal personality, have been thoroughly investigated and stimulated their incorporation into ecology and evolution. Personality is frequently measured using standardised behavioural tests such as open field or dark-light tests. Measures from these tests are often used to draw conclusions about ecological and evolutionary processes in natural conditions, although the direct relevance of standardised measurements for natural situations is not often validated. We compared measures of activity/exploration and anxiety-like behaviour from standardised behavioural tests to to spatial measurements for colonization of a novel, large-scale environment using a grid of antennae to track individual mouse movements. We measured home-range size and quality as well as offspring recruitment after mice established permanent territories in our semi-natural enclosures.

We found that mice which were more active/explorative in standardised tests visited fewer locations during the colonisation period of the experiment, suggesting that comparing results from laboratory test setups to those from more natural situations should be done with care. The relationship between personality and space use after territory formation proved to be more complicated. We did not find a direct relationship between activity/exploration or anxiety-like behaviour and territoriality in the semi-natural enclosures, nor did we find a direct relationship between personality and offspring recruitment. Taken together, these results suggest that a more thorough investigation of movement behaviour and spatial components will further broaden our understanding of the causes and consequences of animal personality.

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Cortisol coregulation between dogs and owners

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Cortisol coregulation' refers to the ability of social dyads to bidirectionally modulate each other's physiological stress levels. Traditionally, research into cortisol coregulation has focused on human social interactions, but a recent study has demonstrated this phenomenon in fish, suggesting that cortisol coregulation is not unique to humans. In fact, new research exploring inter- instead of intra-specific cortisol coregulation suggests that dogs and their owners coregulate their cortisol levels. This PhD research investigates cortisol coregulation between companion dogs (*Canis familiaris*) and their owners and aims to evaluate the factors that influence the strength and direction of coregulation between the dog-owner dyad. Participants repeatedly collect their own and their dog's saliva samples across workdays and non-workdays. In addition, participants also complete a number of questionnaires allowing us to assess daily/weekly routines, the personality of the owner and the dog, and the relationship and attachment levels between dogs and owners. By combining salivary cortisol measures with questionnaire data, we evaluate the influence of dog and owner behaviour and lifestyle, personality, and relationship 'quality' on cortisol coregulation between dogs and owners. This presentation will include an overview of our findings to date and discuss their implications for expanding our knowledge of physiological stress modulation, as well as assessing and improving companion animal welfare.

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The role of edge enhancement in background matching and disruptive camouflage

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Disruptive camouflage is defined as patterning that breaks up the outline of an object, potentially making it more difficult to detect and recognise a target. Recent work has suggested that enhancing the edges of disruptive markings may act to further increase their effectiveness, particularly for identification of targets. However, it is not known whether this edge enhancement effect is specific to disruption, or whether it could also benefit other forms of camouflage, such as background matching. It is also unclear how background-specific the effects are. Here, we conducted two experiments to test how detection and identification of camouflaged targets is influenced by edge enhancement, both for disruptively patterned targets and for background matching targets. In the first experiment, we used a psychophysics-inspired paradigm to measure the critical duration the target had to be presented for to be detected or recognised. In the second experiment, we created an online 'citizen science' game and measured detection times for targets on different types of visual backgrounds. Overall, we found that disruptively patterned targets were generally harder to find than background matched targets, in accordance with previous results. However, surprisingly, we did not find a clear advantage for edge enhancement in any condition, and in some cases, it in fact made the task easier. Therefore, while edge enhancement may sometimes aid disruption, this effect seems to be highly background specific, and we find no evidence that it can extend to other camouflage strategies.

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Where pheasants go to die: does cognitive ability predict where pheasants get predated?

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Most animals utilise a home range. This is assumed to reflect the importance of being knowledgeable about the location of patchily distributed and unpredictable resources such as refuges, food and mates, and also areas that are most safe from predators. Ultimately, the question of why animals exhibit home ranging behaviour is therefore a cognitive one, and yet no studies to date have explicitly addressed whether variation in cognitive ability relates to space use and mortality within an animal's home range. Using the common pheasant, *Phasianus colchicus*, we tested birds on a battery of spatially-related cognitive tasks before releasing them into the wild, where they were then continuously tracked for their entire lifespans until the point they were predated. We found that birds were disproportionately more likely to be predated on the periphery of their home range, although this did not relate to any of the cognitive measures we tested. I will discuss these results in light of the assumed selection pressures driving the formation of animal home ranges.

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Impacts of artificial lighting on the visual ecology of nocturnal hawkmoths

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Artificial lighting at night is a conspicuous and widespread form of anthropogenic pollution, with demonstrated effects on the natural world, impacting the behaviour of nocturnal animals, plant growth, and the interactions between plants and their pollinators. We studied nocturnal hawkmoths (*Sphingidae*), which have excellent vision and are ecologically-important pollinators, to comprehensively model the effects of different types of artificial lights on their visual ecology. We tested how multiple light types would affect perception in the context of several key visually-driven behaviours, from intra-specific communication to predator avoidance and detection of floral signals for foraging and pollination. Using spectrometry, we measured colours from museum specimens of 14 hawkmoth species found in the UK, as well as the flowers and leaves of hawkmoth-pollinated plants and surrounding vegetation. We then modelled how well the relevant colour signals would be perceived, either by the hawkmoths themselves or by potential avian predators, under different lighting types. Our results suggest that artificial lights differentially affect colour perception by hawkmoths and their avian predators, so that some light types, particularly with narrow-band long-wavelength spectra, could be detrimental to hawkmoth behaviour without affecting the ability of potential predators to detect their prey. Our analyses will suggest which aspects of hawkmoth visual ecology may be most vulnerable to disturbance by artificial lighting, and determine which types of lights are likely to be more or less harmful to hawkmoths, providing valuable information to policy-makers considering changes to artificial lighting, such as a move from more traditional lighting types to LEDs.

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Social network structure, long-term associations and reproduction in white rhinoceros

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An understanding of a species' social environment and grouping patterns can be vital for their conservation management. Southern white rhinoceros (*Ceratotherium simum simum*) require intensive management and protection due to the threat from illegal poaching. To maintain genetic diversity, rhinoceros are frequently translocated between different populations. Current translocation strategies take into account the sex, age, and when available, the genetic background of each individual. However, they often do not consider existing social bonds and group dynamics, which may influence individual wellbeing and fitness. White rhinoceros show substantial variation in reproductive success between populations. The impact social conditions have on white rhinoceros reproduction remains unexplored. In this study, we applied social network analysis to two white rhinoceros populations in Kenya, to investigate social structure and natural grouping patterns in the wild. We investigated daily group compositions from two different time-periods, over six months apart, to determine if network structure and inter-individual associations persisted over time. Furthermore, we used individual-level network metrics to determine if network position relates to female reproductive success. Our results show that whilst network structure changed over time, re-association between pairs of individuals remained higher than expected if individuals were associating randomly, suggesting that associations do persist over time. Moreover, our results suggest that females that preferentially associated in cliques, or that frequently connected sub-groups together, had greater reproductive success. Our study provides new insights into white rhinoceros social structure and reproduction that may be relevant to their conservation and breeding management.

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The importance of animal behaviour in conservation science: the example of cheetahs in Namibia

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Studies on the behaviour of elusive and endangered species are challenging and therefore often have to rely on indirect methods such as GPS-collars and camera traps. Nevertheless, such methods have a huge potential, particularly when applying state-of-the-art devices that collect an enormous amount of different data in high temporal resolution and do not interfere with the secretive life of the animals. We used such devices in a long-term study of free-ranging cheetahs (*Acinonyx jubatus*) living on farmland in Namibia. Many farmers live in conflict with the cheetahs because they perceive them as threat to their livestock animals and thus often kill them. The GPS-collars with integrated acceleration (ACC) devices revealed various movement and behavioural patterns of cheetahs. The most conspicuous patterns were different types of clusters, i.e. locations that cheetahs (re-)visited regularly. Physical visits to the clusters in the field and additional behavioural information from camera traps revealed that clusters (i) were used for intra-and intersexual communication, (ii) displayed a feeding event of a prey animal, (iii) showed the death of a cheetah or (iv) indicated a lair of a female that recently gave birth. This information let us identify risky areas for the cattle calves on the farms and assess the intensity of the farmer-cheetah conflict. Additional GPS data of sympatric living leopards revealed very different movement and cluster patterns. We included all this information to develop new research-based conservation strategies for cheetahs and to evaluate current mitigation methods such as translocations of 'problem animals'.

Visual tracking of tiny insects using a freely moving camera while reconstructing their environment

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Automatic locomotion analysis (i.e. tracking) of animals has gained popularity in Biology and Ecology. However, current visual tracking systems fail to track tiny animals like insects in their natural environments for three main reasons: (1) the highly imbalanced foreground / background pixel ratio given small or high recording altitude; (2) the highly varying animal / environment appearance (in particular across different species / habitats); and (3) the presence of clutter, frequent occlusions and low foreground contrast. In addition the necessity to recover the 3D structure of the environment and advanced behavioural features like bearing further aggravate the overall task. To address these challenges we developed a global optimisation scheme using factor graphs to detect even tiny animals like ants (< 5 pixel) in videos recorded with a freely moving camera. Novel machine learning techniques featuring rotation equivariance and optic flow strategies yield additional behavioural characteristics and becomes agnostic to the appearance of the animal and environment. This detection mechanism is accompanied by an adjusted Structure-from-Motion pipeline to also recover the environmental reconstructions and globally referenced camera trajectories while addressing so-called critical configurations potentially corrupting correct three-dimensional reconstructions. Here we will present the latest results of our tracking and reconstruction system in which we particularly investigate the limits of visual object tracking and the impact of critical configurations on the overall performance.

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Studying Behaviour in 3D

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Most animals live in a three-dimensional environment and interact with it, yet studying collective behaviour in 3D remains a challenging task. To study naturalistic behaviour of a group or an individual it is crucial to develop methods, which enable high throughput measurement of the animal's movement in 3D space. Furthermore, 3D position is often not sufficient, and details such as body posture, orientation, or head position are important to answer many questions in behaviour. We introduce a new set-up design for studying collective behaviour of multiple animals in a relatively large indoor 3D environment (15m x 7m x 4m). The setup consists of a commercially available motion capture system capable of real-time tracking using infrared reflective markers, with additional video cameras to compute posture details of animals using computer vision and machine learning algorithms.

Real time tracking allows the possibility of conducting interactive stimuli based experiments with animals.

Lower tracking latency also allows integration of Augmented and Virtual Reality displays as part of experimental setup and interactive data visualisation. The current methods used for tracking 3D posture and action recognition are largely limited to humans due to lack of appropriate datasets for animals. Our goal is thus to create large-scale datasets with our setup that can then be used by researchers in the field of machine learning to develop new solutions for animal posture tracking. Such collaborations are crucial for the development of methods and gaining new insights from collective behaviour studies in the lab and in the wild.

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Swarm formation characteristics and fear-based modeling of Tetra fish

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Self-organizing motion portrayed by flocking birds, insect swarms, fish schools and even bacterial colonies is perhaps one of the most fascinating and yet inadequately understood phenomena in the field of collective behavior. Swarming is utilized as a primary mechanism for defense against predators, better foraging and mating capabilities and increased hydro/aerodynamic efficiency in long-distance migration events. Although the dynamics of swarming motion has received much scientific attention, more work is required to connect the mechanisms responsible for swarm initiation and formation to modeling efforts. This study investigates swarming in Black Tetra (*Gymnocorymbus Ternetzi*) fish triggered by pseudo predators in the form of approaching objects. High-speed video and tagging techniques are used to analyze the swarm and individuals. Observations include reaction times, swarm formation shapes, velocity, density, leadership within the group, etc. A model is then proposed wherein fish have a simple fear vector based on points they can see in their field of view. Friends appear as small collections of dots but if they are moving quickly a fear threshold is heightened in the observer. Large, fast moving objects exceed the observers fear threshold and they propel themselves opposite to the stimulus. Experiments and simulations reveal similar behavior, patterns, response times and wave speeds. Further, the data reveal that fish can transfer information across large groups faster than their individual reaction times and that the wave propagation is not dependent on fish density.

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Individual heterogeneity and intergroup variance in collective behavior

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Cooperative group activity requires consensus and synchronization among individuals. Thus, individual behavioral tendencies must homogenize within the group. This raises the question of whether individuality disappears altogether in collective behavior, or rather somehow manifested in the overall group behavior.

An extreme example of synchronized group behavior is that of collective motion, the concurrent spatial translation of many individuals. Swarming insects, in particular, can organize in synchronized groups of millions that cover vast areas. We studied marching locust nymphs under controlled conditions in order to uncover the interdependency between variability in the behavior of individuals and that of groups. To this end, hoppers were individually tagged with barcodes, enabling their consistent identification and tracking while walking in a ring-shaped arena. We compared the behavior of single animals, small groups, and virtual, non-interacting groups composed of randomly-shuffled trajectories of individuals from real groups. Two types of behavioral characteristics were identified: (1) those that differ between single animals and groups, while remaining conserved among groups, suggesting their importance in the formation of collective motion; and (2) those that are heterogeneous among groups, but homogenized within a group, and thus give rise to distinct group characteristics. Computer simulations showed that the observed intergroup variance could result solely from the unique combination of the individual locusts composing the group, differing only in their socio-behavioral tendencies. These findings indicate that individual variance can generate distinct group-level characteristics, even in the highly synchronized collective motion phenomenon; and thus demonstrate the importance of individual variance in collective behavior.

Shall I come again? Site fidelity in a group of Northern Bald Ibis (*Geronticus eremita*)

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With only about 700 individuals left in the wild in the Souss Massa National Park in Morocco, the Northern Bald Ibis (*Geronticus eremita*) is a highly endangered avian species. Little is known about the general spatio-temporal patterns of these birds, which is very important for conservation to protect the remaining colonies and for the success of reintroduction projects. Especially local enhancement and hence simple socially transmitted information of the location of food plays an important role regarding foraging decisions. In the present study, thirty-two Northern Bald Ibises of the free-flying and individually marked colony of the Konrad Lorenz Research Station in Upper Austria were fitted with GPS transmitters from 2013 to 2016. The colony was established in 1997 for basic research of social behaviour and to gain knowledge for reintroduction projects. We studied their movement behaviour with a focus on site fidelity and revisitation rate of foraging grounds within their home range. Generally, individuals showed a high site fidelity and preferred specific foraging grounds over the years with seasonal patterns in the revisitations of the preferred locations. Our results indicate that Northern Bald Ibises are conservative in their use of space and resources and further contribute core-knowledge for reintroduction projects. As the colony forages together or splits up in small groups during foraging, habitat quality cues from specific individuals could be used by other colony members. This knowledge can help to identify such target areas to subsequently protect them in remaining populations or reintroduction projects.

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Signal manipulation alters the integration of social behavior, physiology, and performance.

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Signals that mediate repeated social interactions have the potential to drive dynamic feedback between signaling phenotype, physiology, and the social environment. Thus, signals might play a causal role in generating integrated phenotypes among a set of flexible traits. We previously found that the brightness of the white breast feathers in female tree swallows is correlated with social behavior, corticosterone, and stress resilience. We hypothesized that integration of this suite of traits might be maintained by the experience of repeated social interactions that are mediated by signaling. In this study, we experimentally dulled female breast feathers during the breeding season. We identified ~40,000 instances of an individual visiting a box at which they were not part of the breeding pair using an RFID network. Relative to controls, dulled females initiated fewer trips and were visited less often by neighboring males. Dulled females also differed in several physiological measurements and fed their own nestlings at a higher rate. Ultimately, dulled females fledged significantly more offspring at their own nest despite having similar clutch sizes and initiation dates as controls.

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Distributed information transfer in slime mold *Physarum polycephalum*

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Physarum polycephalum, despite lacking neurons, has demonstrated information processing capabilities that help it thrive in challenging environmental conditions. It is a single-celled, macroscopic, multi-nucleated protist that self-organizes into a complex system of intersecting tubules. *P. polycephalum* is capable of remarkable problem-solving behaviors, but the mechanisms underlying these behaviors are poorly understood. They are believed to be encoded in the cyclical contraction-relaxation pattern of its membrane, which is composed of multiple contractile regions that respond to the quality of the local environment and the contractile pattern of the neighboring regions. In a recent study, we showed that, when *P. polycephalum* tubule segments were given a choice between two food sources, the direction of information transfer varied with the difference in quality between the food sources. In particular, when the food sources differed in quality, the contractile regions near the rejected food source acted as the information sources (i.e., as the drivers of the behavior) and the regions near the chosen food source acted as the information destinations. To explain this counterintuitive result, we will present here a mechanistic model suggesting that the behavior of the slime mold may actually be driven by an increased relaxation of the membrane near the chosen food source relative to the baseline contraction-relaxation activity of the rest of the tubule. Under this new paradigm, we can reproduce our experimental results and propose new testable hypotheses to explore the link between the behavior of *P. polycephalum* and the active matter characteristic of its membrane.

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Fighting cichlids: morphometric and hormonal analysis to understand female and male aggression

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Even though aggression in males has been historically linked to androgens, recent evidences suggest that the key step regulating this behavior involves aromatization to estrogens. Even if females from different species also display aggressive behavior, aggression has been usually studied in males competing for resources and female aggression is still understudied. The challenge hypothesis suggests that behavioral interactions lead to an increase in plasma androgen levels in response to social instability. *Cichlasoma dimerus* is a monogamous Neotropical cichlid with bi-parental behavior, in which both males and females show aggressive behavior. In this context, the aims of this study were: a) to perform network correlation analysis of morphometric and hormonal variables in order to understand individual variability in aggressive behavior; b) to determine whether there is a relationship between sex steroids plasma levels and intrasexual aggression in the context of the challenge hypothesis. Sex steroids were determined before and after intrasexual dyadic agonistic encounters and morphometric variables were measured. All agonistic interactions were recorded for one hour and aggressive and submissive displays were determined in each animal. Network correlation analysis suggests that morphometric and hormonal variables can differentially explain individual aggression not only in males but also in females. Moreover, initial estradiol plasma levels can predict winner status and aggression in females, but not in males. Finally, during male encounters there was not only an increase in androgen levels but also in estradiol levels, suggesting that the challenge hypothesis could be extended to estrogens.

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Primate socio-endocrinology revisited: new tools to tackle old questions

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Links between fitness proxies and individual differences in sociality are repeatedly reported in human and non-human primates. Generally, individuals with more social contact or stronger social bonds enjoy benefits such as increased survival and reproductive output. The supporting body of endocrinological evidence, in turn, highlights the negative correlation between physiological stress-levels and secure social bonds. However, due to methodological restrictions, questions regarding the mechanisms that connect social environment (and particularly sociopositive exchanges) and hormone-behaviour interactions remain unanswered. Bio-logging techniques allow continuous and synchronous monitoring of the behaviour and position of multiple individuals within a group, revealing a fine-scale representation of each individual's social environment. Thus, we can address how sociopositive behaviours are given, reciprocated, and distributed across a network of potential partners. This, together with regular and frequent non-invasive assessment of physiological stress-levels (i.e. from urine and faeces), allows us to link short- and long-term hormone profiles to sociopositive interactions. Sixteen Cape chacma baboons (*Papio ursinus*) were tracked on the Cape Peninsula, South Africa using high-resolution collars built at Swansea University, collecting both accelerometer and GPS data (40 Hz and 1Hz sampling frequency, respectively) for several months. During this period, observational data were also collected, allowing for the comparison of traditional and new methods in the field of socio-endocrinology. Here, we demonstrate the first steps of obtaining grooming data from bio-loggers and present preliminary findings from behavioural and hormone analyses. This work will contribute to a better understanding of the relationship between sociopositive interactions and physiological stress-levels in primates.

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Let it go: macaws wait for better rewards in a self-control paradigm

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The ability to control impulsiveness to gain higher, but delayed pay-offs has been suggested to increase individual fitness and has been demonstrated in several species across different taxa. One of the methods used to investigate self-control is the delayed gratification task that requires subjects to avoid an immediate but less preferred reward in order to obtain a better but delayed one. First results indicate that birds perform comparable to primates in this complex impulse control task.

We performed a delay of gratification test with two different but closely related parrot species: great green macaws (*Ara ambiguus*, AA) and blue-throated macaws (*Ara glaucogularis*, AG). During the task, subjects were given a choice between an immediate lower quality reward (= LQR) and a delayed higher quality reward (= HQR) presented sequentially on a rotating tray. Control conditions were implemented to test for location preferences (i.e. both options contain LQR) and avoidance learning (i.e. HQR comes first). Our preliminary results showed that the AA, on average, tolerated a greater delay ($\bar{x}$=23.12s) than AG ($\bar{x}$=10.00s), although both species had a maximum delay of 30 seconds. However, the AG showed higher individual variation (SD=10.95) than the AA (SD=8.42).

Notably, the individuals of both species that tolerated higher delays distracted themselves (e.g. manipulating objects) while waiting, which compares with some previously tested species. Overall, the macaw species tolerated delays lower than the few previously tested parrot species, suggesting that the differences in their self-control abilities may reflect adaptations to species-specific foraging ecology.

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High CO2 conditions disrupt cleaner fish cognition but reveals potential for adaptation

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Ocean acidification due to increased CO2 absorption is one of the many consequences of climate change. Various studies suggest that marine organisms' sensory functions will be impaired under extreme scenarios (980 µatm). However, these studies involved short term CO2manipulations and do not consider the potential for adaptation through natural selection. Here we show that the cognitive performance of Indo-Pacific cleaner wrasse, *Labroides dimidiatusis* unlikely to suffer, at least as long as 750 µatm is not exceeded. After gradual change of pCO2 levels, we acclimated cleaners to both pre-industrial and future scenario levels over 30 days before we tested fish in an ecologically relevant task, the ability to prioritise an ephemeral food source over a permanent one. Fish cognitive performance remained stable from pre-industrial (275 µatm) to present-day pCO2levels (404 µatm). While performance was drastically reduced under both mid and high CO2 scenarios, some cleaners retained a normal cognitive performance under mid CO2, suggesting the existence of tolerant individuals among today's cleaners standing genetic variation where natural selection can act on, as long as strong selection pressure on cognitive performance exists.

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Neurally underdeveloped cuttlefish newborns exhibit social learning

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Learning can occur through self-experience or through the experience of others. The latter allows for adaptive behaviour without trial-and-error, and generally maximizes individual fitness. Given their mostly solitary lifestyle, cuttlefish have rarely been tested under observational learning scenarios. Here we tested if neurally-underdeveloped *Sepia officinalis* hatchlings (up to 5 days) incorporate social information, by observing conspecifics perform a task where inhibition of predatory behaviour is learnt. Our results show that more observers than demonstrators learned the task, while also reaching learning criterion in fewer trials. Moreover, observers always reported less attacks and higher latency time to attack during trials. Our findings reveal the vicarious capability of cuttlefish newborns to learn inhibition of predatory behaviour, potentially through emulation (i.e. affordance learning). Despite ongoing changes on neural organization during early ontogeny, this cognitively-demanding form of learning is already present in cuttlefish early stages, facilitating behavioural adaptation and potentially improving individual fitness in the environment.

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Problem solving in cockatoos and robots: emulating animal cognition with synthetic intelligence

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The growth of comparative cognition has yielded discoveries of Surprisingly Complex Behaviour (SCB) in taxa as different as apes, birds and social insects. Interpretations of SCB based on 'mental' representations, consciousness, or insight have recently re-appeared in scientific publications, but are hard to define operationally and can turn into empirical dead-ends. An alternative is to emulate SCB observations in experimentally accessible frameworks, combining prior predispositions, learning by experience, generalization, working and reference memory, and explicit models of internal representations. This integrates behavioural biology with the rapidly growing field of synthetic intelligence systems, especially autonomous robotics. We are pursuing such an approach, investigating complex problem-solving behaviour by Goffin cockatoos and emulating their SCB in virtual and physical synthetic systems. Our basic task is gaining access to a reward (food or self-plugging in a mains outlet) after opening a cascade of inter-connecting locking devices, and our theoretical tools are both model-based and model-free reinforcement learning algorithms with strong dedicated prior features.

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Heterospecific song quality constitutes social information for settlement decisions in a wild bird

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Heterospecific social information use for breeding habitat selection, i.e. information derived from the observation of other heterospecific competitors and their settlement decisions, is considered as an important behaviour structuring multi-guild populations. Because gathering information about possibly dominant competitors may involve agonistic costs, the use of cues acquired from a distance but reliably predicting local success should be favoured. In particular, bird songs are conspicuous signals assumed to reliably reflect producer quality, and thereby local site quality, and could thus constitute valuable information sources for conspecific and heterospecific competitors. It is however unknown whether fine-song features other than simple contact calls may cross species boundaries. We experimentally tested this hypothesis on a wild population of collared flycatchers (*Ficedula albicollis*), a species known to eavesdrop on great tits (*Parus major*) presence and performance. Using a playback experiment, we tested whether flycatchers preferred to settle near broadcasts mimicking the presence of a high quality great tit (songs with large repertoire size, long strophes, high song rate), a low quality great tit or a chaffinch (control). Among old females, aggressive ones preferred to settle near broadcasts of high quality tit song, while less aggressive old females preferred to settle near broadcasts of low quality tit song. Male traits did not influence settlement decisions. Thus collared flycatcher females use great tit song quality-features as information for settlement decisions, but differently depending on their own competitive ability and age or experience. These results extend our view of heterospecific social information to fine sexual signals compositions.

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Development and retention times of behavioural performance predict the evolution of plastic behaviour in unstable environments

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Theory shows that high environmental instability selects for fixed rather than plastic phenotypes, because of lag-time constraints (i.e., the time to adapt to environmental change). Since behaviour can change rapidly, the lag-time constraint has been dismissed as not relevant for behavioural plasticity, and it is often argued that responsive behaviour (i.e., plastic behaviour that responds to the environment) should evolve to cope with unstable environments. But performing a behaviour efficiently may require time for learning, practicing or, in social animals, for the group to adjust. Likewise, not using a behaviour can over time reduce its level of performance due to memory constraints, lack of practice, or mismatch with the group. We show, using individual-based simulations, that the evolution of responsive behaviour does not depend on the absolute length of time to develop or to retain behavioural performance, but instead depends on the relation between the two. Above a threshold of development/retention times, increasing environmental instability leads to the evolution of fixed behaviour; below that threshold, responsive behaviour is selected even in maximally unstable environments. Our results generate novel predictions as for when responsive behaviour should evolve, as opposed to more fixed behavioural strategies, such as those seen in animal personality.

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When water meets temperature: behavioral thermo-hydroregulation in a terrestrial ectotherm

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The regulation of body temperature (thermoregulation) and regulation of water balance (define here as hydroregulation) are key processes underlying ecological and evolutionary responses to climatic conditions in wild animal populations. In terrestrial or semi-terrestrial ectotherms, thermoregulation and hydroregulation closely interact and combined temperature and water constraints should directly influence individual performances. However, in ectotherms studies, behavioral and physiological hydroregulation have been overlooked. Behavioral hydroregulation is also often studied independently of thermoregulation, and too few studies highlighted the effect of water on body temperature regulation. We demonstrate how thermo-hydroregulation provides a framework to investigate functional adaptations to joint environmental variation in temperature and water availability. We detail for example why we expect some behavioral conflicts between thermoregulation and hydroregulation, as a heating organism also loses more water. In a second part, we aim at showing some empirical support of this framework with empirical behavioral studies on the common lizard (*Zootoca vivipara*) in controlled and semi-controlled conditions. The first results of our team highlight different patterns of activity and micro-habitat selection in response to both water and temperature constraints in the environment. This knowledge that still have to get deepened could have important ecological but also evolutionary implications.

How viewing objects with the dorsal or ventral retina affects colour-related behaviour in guppies (*Poecilia Reticulata*)

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Colours are used for species recognition, aposematic signals, camouflage, and mate choice. In aquatic environments, coloured cues can be viewed from above or below individuals. For small fishes, such as guppies (*Poecilia reticulata*), food is usually found either at the water surface or on the stream bed. These two locations have very different visual backgrounds. Moreover, during courtship, the male generally displays in front of or slightly below the female. Those differences in behaviours may be related to differential expression of opsin genes in the dorsal and ventral retina and between females and males. We tested the spectral sensitivity of guppy males and females with stimuli viewed from below and above the body axes. Twelve different wavelengths, collectively stimulating all of the guppy cones, were tested. We found that wavelength, position and speed of the stimuli influenced male and female behaviour and seems to be mediated by the long wavelength sensitive photoreceptors. Males also had stronger behavioural responses than females whereas females performed more foraging-related pecking behaviour. Our results suggest that the spatial requirement of visual tasks and their ecological context are important and appear to be partly correlated with photoreceptor arrangement in the retina.

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Chimpanzee (*Pan troglodytes*) navigation in a virtual 3D foraging game

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Primate navigation has been studied in the wild and in captive environments. While captive studies allow for greater experimental control, space limitations severely limit the generalizability of results to natural contexts. We introduced six chimpanzees at Leipzig Zoo, Germany, to a novel virtual 3D testing game. Chimpanzees operated a touchscreen to guide an avatar through a cartoon style arena that contained grassy hills and bushes as well as trees and other obstacles, in order to collect virtual fruit. After training subjects to reliably navigate to the same goal location (a tree with multiple pieces of fruit under it), we presented subjects with novel challenges (e.g. navigating to the same location from different starting points and with different starting orientations; navigating to a novel goal location). Most subjects learned to steer the avatar (walking, turning, orienting on the spot) over a small number of testing sessions. All six subjects learned to navigate to the same goal from different starting points over the course of six to twelve testing days, even when they could not see the goal at first. In addition, three subjects quickly learned to travel to a second, hidden goal location when no fruit was present at the original goal location, with one subject even taking novel shortcuts on its way to the new location. We propose to use virtual 3D testing environments such as this to study potential mechanisms of primate navigation (e.g. path integration, landmark use, cognitive maps) in greater depth than was previously possible.

Factors shaping the gut bacterial communities of wild red-fronted lemurs (*Eulemur rufifrons*)

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The gut microbiome is important for the development of the gastrointestinal immune response, food digestion, vitamin production, susceptibility to disease and regulation of the physiological stress response. Thus, it plays a pivotal role for the health of an animal. The composition of the gut microbiome of an individual can be shaped by several factors. These include intrinsic factors like age, sex, genetics, and the physiological stress response, and extrinsic factors like diet, social interactions, and gastrointestinal parasites. Particularly, social interactions appear to be key in shaping the gut microbiome composition. To determine the composition of the bacterial gut communities of wild lemurs and their potentially impacting factors, we studied 4 groups of red-fronted lemurs in Kirindy Forest in Madagascar for a period of one year. Fecal samples were collected monthly per individual to determine the gut microbial community accompanied with daily behavioral observations. Preliminary results from 16S rRNA gene analysis showed that the main bacterial phyla present are *Bacteroidetes*, *Firmicutes*, *Spirochaetes*, and *Gammaproteobacteria*. Particularly, abundances of *Bacteroidetes* differed between the groups, suggesting that group membership is key to the gut microbiome composition. Further processing and analysis of the data and samples will address the effects of seasonality, diet, and social interactions on the bacterial community of individuals. Herewith, we contribute to the emerging understanding of the interrelationship of factors influencing gut microbiota compositional dynamics and, thus, central links of the sociality-health nexus in a wild primate.

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Spatial organization of food distribution on the nests of the primitively eusocial paper wasp *Ropalidia marginata*

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In social insect colonies, food transferred through space and time via nestmates carries both nutrition and information. We followed, spatially and temporally, food brought into semi-natural colonies of a tropical paper wasp *Ropalidia marginata*, to understand the mechanism and efficiency of its distribution among adults as well as to larvae. Wasps divided the tasks of bringing food to the nest and feeding larvae, among themselves. Using the analogy of the travelling salesman problem and the Hamiltonian path problem, we found that individuals optimized their routes in order to feed the randomly distributed larvae. Within each feeding bout, different feeders randomly fed larval cells resulting sometimes in repetitive feeding of the same cells by different wasps. This lack of spatial segregation of their feeding effort helped provide redundancy that should avoid larvae going hungry. Considering all the bouts put together, the larvae closer to the centre of the colony were fed significantly more frequently than larvae at the periphery. The cause of this variation could be the nest's geometry and needs to be studied further. The consequence of differential rates of larval feeding can, however, shape the fate of these larvae; previous work has shown that well-fed larvae develop into adults that are more likely to become egg-layers while poorly-fed larvae develop into adults more likely to become non egg-layers. Understanding the spatial organization of food transfer may be a key to understanding how insect societies achieve efficient social organization and division of labour.

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Locomotor adaptations reflect differences in habitat use between four frugivorous rainforest mammals

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Foraging animals move through their habitat responding to a diverse set of environmental and social cues. The exact paths they take as they navigate between resources depends on the interaction between their motion capacity and the physical constraints imposed by habitat structure. We compared the fine-scale movement decisions of four Neotropical frugivorous mammals--capuchins (*Cebus capucinus*), spider monkeys (*Ateles geoffroyi*), kinkajou (*Potos flavus*) and coati (*Nasua narica*)--during a season when *Dipteryx oleifera* was the only available fruiting tree species. Using data from high resolution GPS-tracking, drone-based mapping of fruit trees, and LIDAR derived metrics of habitat structure, we built step selection functions to elucidate the environmental features driving individuals movement decisions, and test the hypothesis that species with more specialized locomotor adaptations and stricter canopy use (spider monkeys and kinkajou) show stronger habitat preferences than species with a more generalized locomotor morphology and less restricted canopy use (capuchins and coati). All species preferred taller canopy and avoided routes with high elevation gain, with the strongest effect on spider monkeys and the weakest effect on kinkajou. Semi-terrestrial species avoided heavily sloped terrain, with strictly arboreal species unaffected. All species except capuchins avoided canopy gaps and preferred areas with canopy cover, with the strictly arboreal species the most strongly affected. All species minimize their distance to fruiting trees. Species-specific trends in habitat use reflected locomotory specialization, but there was also surprising inter-individual variation. Our results demonstrate how different motion capacities result in discrete strategies of habitat utilization given shared environmental constraints.

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Estimation of attraction and repulsion forces working among individuals in feral horses

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Life is dictated by the forces acting upon us. In animal groups, the most representative example is the attraction and repulsion forces that influence group cohesion. The low of attraction and repulsion proposes individuals adjust distance to neighbors, following force working among individuals. Although theoretical studies have reported the effectiveness of this rule, field studies are relatively few, especially in large non-human mammals. Therefore, it is still unknown how these forces actually work among individuals and the effective range of both attraction and repulsion forces. In the present study, we quantified both forces and estimated the effective range by combining the field observation in feral horses with verification by mathematical simulation. Horses are highly social and maintain constant membership within one group. We constructed agent-based models based on a simple repulsion and attraction model and compared it to observed data recorded with UAVs. Metric, topologic, and exponential decay were the interaction types considered in our models. Our results are threefold results. First, metric interaction in our simulated models best fit the observation data. Second, repulsion force was estimated to be a maximum of four body lengths. In other words, horses perceived personal space may be within four body lengths. Third, inter-group differences were found which suggest group interaction range can be plastic or other types of forces influence group cohesion. Our study is one of first to quantify attraction and repulsion forces in feral horses.

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Quantifying exploitative competition in Neotropical frugivores

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Understanding the strength of competition between species over a food resources is an essential element in ecology. When multiple species are dependent on a single common food resource exploitative competition should be at its highest. In 2015-2016 and 2017-2018 we fitted three neotropical frugivores (white-faced capuchin, Geoffrey's spider monkey and white-nosed coati) with high-resolution GPS collars on Barro Colorado Island, Panama, during a season where the primary fruit resource comes from *Dipteryx oleifera*. Flowering *D. oleifera* were identified from drone footage for both years. To ensure the frugivores were in audible or visual range of each other dyadic distances was set to max. 50 m and with at least one individual being within max. 20 m of a fruiting *D. oleifera*. Data from 200 fruit-fall traps (grams/m2/week) was investigated as predictor for number of encounters and encounter durations. GPS data was randomized to investigate if our encounter data was different to random chance. Encounter outcomes were assessed by creating videos of the tracks for the individuals and scored according to three possible outcomes: co-occurrence, displacement and avoidance. Number of daily encounters and daily encounter durations were predicted by *D. oleifera* fruit-fall as both positive, neutral and negative relationships. Encounters were different from random and the primates had the strongest level of competition of in the form of displacements, short durations and fewer encounters. Niche differentiation theory explains how the strength in exploitative competition changes with food availability and this study provides framework to quantify it.

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Which factors influence movement and association patterns of non-breeding ravens?

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Most animal social groups show some form of temporal variation in group size and composition i.e. fission-fusion dynamics. It remains largely unknown which social and ecological processes drive these group dynamics. Common ravens (*Corvus corax*) live as non-breeders in highly dynamic fission-fusion groups during their first three to even more than ten years. They show large individual variation in movement distances (few to hundreds of kilometres) and different durations of temporary settlements close to rich food sources (from days to years). This system leads to repeated associations of many individuals at the same and different locations, where socio-positive behaviour and alliance formation in agonistic interactions can frequently be observed. We studied the effects of sex, age and genetic relatedness on movement and association patterns in non-breeding ravens. Over the last 10 years we individually marked around 300 ravens, estimated their age, collected blood samples, recorded almost daily their associations at a rich food source and additionally GPS-tagged more than 50 non-breeders. Our results revealed no indication for sex differences but with increasing age non-breeders associate with local groups less frequently. Further, non-breeding ravens increase their use of a specific food source, if their nest siblings are present as well. This is also supported by observations from captivity, where siblings often form strong social bonds to outcompete others in rank and access to resources. Together, these results underline the importance of the social environment as a driver for individual movement decisions.

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Visual landmarks and experience affect where and how wild hummingbirds search

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Currently, there are two methods for studying how spatial memory shapes animal movement: the comparative cognition approach which trains animals to use specific cues, but rarely examines the details of movement beyond a few key behaviours; and the movement ecology approach which uses animal-borne trackers to collect the details of animal movement but can only indirectly infer the role of spatial memory. While each approach has its advantages and limitations, they are rarely used in combination. In this study we combined the methods used in comparative cognition and movement ecology to examine how the learning about visual landmarks affects the searching behaviour of wild hummingbirds. We trained wild hummingbirds to find a reward relative to a pair of landmarks, and in tests the reward was removed and the birds' movements tracked in 3D. Using Hidden Markov Models, we classified hummingbird movements into different behavioural states, including 'travelling' and 'searching' and analysed how experience and presence or absence of the landmarks in the test affected: 1) where and when states occurred; 2) the probability of transitions between states; 3) the patterns of speed and turning within each state. The presence of the landmarks not only influenced where hummingbirds searched, but also how birds allocated their time, as well as when birds changed between states, and even the properties of the behavioural states themselves. This study demonstrates the benefits of combining experiments from comparative cognition with analyses from movement ecology, providing both experimental control and insights into the details of animal movement.

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Fruit investigation behaviors vary with color vision phenotype in wild capuchin monkeys

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Senses serve as the interface between animals and their environment and play a critical role in food detection and evaluation. Color and/or scent changes during ripening may attract frugivores and inform their investigation behaviors. While numerous studies have assessed the impact of color on fruit selection, comparatively little is known about fruit scent, and how olfactory and visual data are integrated during foraging. We combine 25 months of behavioral data on 75 white-faced capuchins (*Cebus imitator*) with measurements of fruit reflectance spectra (color) and plant volatile organic compounds (scents) from 18 dietary plant species at different ripeness stages. We show that the frequency of sniffing behaviors - a proxy for reliance on the sense of smell - is positively correlated with increases in the volume of fruit odorants during ripening. Additionally, monkeys with red-green colorblindness (dichromacy) sniffed fruits more often, indicating that increased reliance on olfaction may be a general behavioral strategy that mitigates decreased capacity to detect red-green chromatic contrast. These results demonstrate a complex interaction among fruit traits, sensory capacities and foraging strategies. By examining fruit traits and sensory investigation of seed dispersing mammals, we help elucidate the evolutionary relationships between plants and frugivores and explain variation in primate behavior.

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A Comprehensive Framework for the Analysis of Colour Patterns in Nature

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The behaviour, ecology and evolution of almost all animals is affected by vision, whether that of a competitor, potential mate or predator. Animal vision is hugely diverse, particularly when considering spatial acuity and the range of wavelengths their eyes are sensitive to. What might look like a powerful visual signal to one animal could be perfectly camouflaged to another. Quantifying the appearance of scenes based on the vision of the receiver is therefore essential. To date, colour and pattern have typically been analysed separately, often without appropriate control for viewing distance. A number of sophisticated spatio-chromatic analysis techniques have been devised, but these have rarely been adopted by researchers because they require expensive equipment, prohibitively laborious data collection, and computer coding skills. We have therefore developed the 'quantitative colour and pattern analysis' (QCPA) framework, which offers an unprecedented range of different spatio-chromatic analysis and data visualisation tools, all based on free, open-source user-friendly software. The framework uses calibrated digital imaging, supporting almost any camera type (even smart-phones). These images are converted to animal-vision cone-catch quanta, and then a series of novel algorithms are used to apply acuity and viewing-distance correction, reconstruction of sharp chromatic edges, and the clustering of images into discrete colours. All of the processing makes use of the 'receptor noise limited' colour model together with spatial acuity correction, which we believe makes our framework the most comprehensive, sophisticated and behaviourally validated suite of animal vision analysis tools to date.

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Towards automatic receptive field mapping in 'social state space' by 3D videography

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Measuring mouse social behavior is difficult. Mice are small, their movements are fast, and mice move in 3 dimensions (during mounting, for example). Currently, most studies of social behavior rely on labor-intensive methods, such as manual annotation of individual video frames. These methods are susceptible to experimenter bias and have a very limited throughput. We present an experimental setup and a robust calibration and tracking method that allows us to measure the behavior of multiple freely moving mice in 3 dimensions with high spatial and temporal precision (90 frames/s). In addition to this 3D data, we collect accelerometer data and record ultrasonic vocalizations (which are classified into call types using unsupervised clustering methods). These data allow us to construct a matrix representation of the 3D postures and movements (within and between mice) and patterns of ongoing ultrasound vocalizations - a kind of 'social state space'. This representation gives us a fine-grained read-out of social behaviors and how they change with manipulations of neural circuits. We are currently doing two things: (1) We are working on approaches to analyze this type of data to discover structure in social behavior in a purely data-driven manner. (2) We are combining this behavior setup with silicone probe neural recordings to map firing patterns of both single neurons and networks in the social state space.

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Windows of perception and collective sensing in animal groups

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Pooling of information often allows larger groups to make more accurate decisions than smaller groups. Many models suggest this improved accuracy depends on group members gathering information relatively independently from one another. Is there evidence that group-living animals coordinate the behaviour to sample information independently? Using a virtual prey experiment, I will first show that the visual perceptual abilities of individual fish are limited both in space and time, with self-induced motion reducing individuals' capabilities of detecting prey. This will demonstrate, therefore, that individuals have key 'windows' when their likelihood of detecting information is higher. I will then show that in groups, individuals offset these perceptual windows, thereby making information gathering more independent between one another. Consequently, I will show this independent gathering of information allows groups to detect visual information in their environment that individuals are less likely to detect if alone. This work lends new insights into the strategies animals use to collectively detect information, ultimately leading to more accurate collective decision-making.

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Pair-bond stability does not benefit reproductive performance of breeding pairs

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Pair-bond formation and stability is key for reproduction of mated individuals. Pair-bonded individuals engage in reciprocal interactions that facilitate the emergence of cooperative activities that increase reproduction and therefore fitness. Thus, it is key to understand the role of pair-bond stability and the social mechanisms by which individuals can increase their reproductive performance. Here we used a captive population of zebra finches, *Taeniopygia guttata*, a species that form lifelong pairs resulting from mutual mate choice, to characterise the process of pair bond formation, its temporal stability, and how these translate to reproductive outcomes. We used a state-of-the-art high-resolution tracking method to monitor social associations across 180 individuals in 4 replicated aviaries occurring during the pre-breeding season, quantifying the strength and stability of the pair-bond, and measuring parameters of following reproduction. Our results indicate that pair-bond formation is a complex process. Contrary to our expectations, socially pair-bonded pairs that were stable before the breeding season did not started their clutch earlier in the season, nor did they have larger clutch compared to those that were less stable during the pre-breeding season. This indicates, that other mechanisms that favour reproductive performance should be in place, and that perhaps pair-bond stability may have other non-reproductive benefits. These results contribute to better understand the dynamics of processes, such as the development of social structure, and sexual selection, especially in monogamous species.

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Mate encounter in a multimodal duetting system

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Pair-formation strategies are affected by the spatiotemporal distribution of potential mates. The paleotropical false-leaf katydid *Onomarchus uninotatus* exhibits a unique multimodal duetting system. Males use long-range acoustic signals and females respond with short- range vibratory signals, which are then used by males to localise the females. Being a canopy species, this presents a paradox. While male acoustic signals can be perceived over relatively long distances and thus by females located on a different tree, female vibratory responses cannot be perceived by males across trees. For the across-tree scale, we studied the spatial structure of calling males in their natural habitat and, together with information on female hearing thresholds and host plant (*Artocarpus spp.*) distribution, computed the perceptual spaces of male calls and found that females could hear calls of males from neighbouring trees with a probability of 0.6. We then investigated female responses to male acoustic signals played back from loudspeakers that were not connected to the substrate on which the females were placed. Females typically tremulated first, followed sometimes by initiation of flight, suggesting that females may perform flight phonotaxis to locate calling males on a different tree. We then used a simulation framework to study the optimal mate encounter strategies that males and females can employ at the across-tree spatial scale. We varied the across-tree spatial distribution of the sexes and quantified the encounter efficiencies for different movement patterns, using the data on spatio-acoustic patterning of callers in this system.

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Within-individual variation in divorce and extra-pair paternity in blue tits (*Cyanistes caeruleus*)

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Several studies investigated variation in the frequency of divorce and extra-pair paternity (EPP) between individuals. However, our knowledge about within-individual consistency and about environmental factors that influence within-individual changes in mating patterns remains limited. We used a dataset based on 18 breeding seasons from two populations of blue tits to investigate within-individual consistency in pairing status (divorce), the occurrence of EPP, the number of extra-pair young (EPY), and the number of extra-pair partners (EP partners). We further tested whether between-year changes in levels of EPP could be predicted by changes in the local social breeding environment. Repeatabilities for mating patterns were low to moderate, but significant for the likelihood to divorce in females and for the occurrence or levels of EPP in males and in females. We found no evidence that the presence of the former social partner, the proportion of familiar individuals or phenotypic traits of the neighbours influenced levels of EPP. For females, an increase in territory size was associated with an increase in the number of EP partners and an increased likelihood to gain EPP. Our study indicates that mating behaviour is primarily a context-dependent trait. The expression of EPP might be highly flexible depending on suitable opportunities or coincidental 'meetings' of two individuals leading to variation in within- and extra-pair copulations and on post-copulatory processes. We propose that future research should now focus on potential carry-over effects of the non-breeding or early breeding season on the mating patterns.

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Empirical dynamic modelling for the study of complex mate choice systems in *Poecilliidae*

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Sexual Selection is perhaps the most complex idea in evolutionary biology. It is this seemingly unbound creative potential which makes it so interesting and seemingly difficult to study quantitatively. By leveraging machine-learning and statistical physics, we are beginning to develop robust quantitative descriptions of behavior. Here we present empirical data driven dynamic models of behavior in freely interacting male and female guppies as well as generative models of male ornamentation patterns. The metrics calculated from this representation provides quantitative insight on essential elements of courtship including control and information transfer between individuals and provide an equation-free predictive framework to explore. We highlight the relationships between the variation in ornamental signals and courtship behavior as well as robust quantitative description of female preference and male reproductive tactics. In the future, these techniques and others from complex systems science will provide a rich toolset to further explore the strange manifolds of co-evolutionary aesthetics across taxa.

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A simple efficient foraging strategy to exploit a replenishing resource under competition uncertainty

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Every spring tens of thousands of female lesser long-nosed bats (*Leptonycteris yerbabuenae*) arrive pregnant to a maternal cave in the Sonoran Desert of Mexico after a long migration of more than 1000 km from central Mexico. During the lactation period, they rely on the nectar, pollen, and fruit of the Saguaro cacti (*Carnegiea gigantea*) as their main food source, while the Saguaro relies on these bats as its main pollinator. In order to reveal the foraging strategy of the lesser long-nosed bats, we used miniature GPS devices with an ultrasonic microphone to track bats' movement and behaviour. We used a drone to create a 3D model of the visited cacti fields, characterized the cacti distribution and the number of open flowers. Analyzing bat movements in relation to their food distribution allowed us to identify visits to a specific cactus. We found that lesser long-nosed bats conduct long commutes every night, flying up to 103 km each way from the cave to the foraging site. They concentrate their feeding in a specific area inside the cacti field, visiting specific cacti very often thus maintaining a foraging home-range throughout the night and during consecutive nights. Using a model with minimum memory, we show that bats revisit cacti according to their previous experience. Our results demonstrate a simple efficient strategy for foraging under competition uncertainty.

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Dive Like a Penguin - Foraging Flexibility of Chinstrap Penguins in the South Shetland Islands

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With the expansion of the krill fishery in Antarctic waters, and the disproportionate effects of climate change on the continent, understanding how krill-feeding animals respond to changes in the abundance and distribution of their prey is necessary for the mitigation of anthropogenic threats on Antarctic wildlife. Chinstrap penguins feed almost exclusively on krill, and cannot switch prey species when krill availability is low, thus their capacity to dynamically adapt their foraging behaviour to the distribution and availability of krill will affect their survival into the future. To understand their foraging flexibility, we studied the diving behaviour of chinstrap penguins across 4 islands in the South Shetlands between 2011 and 2016. We compiled GPS and temperature depth recorder (TDR) data from foraging trips of 171 chinstrap penguins, totaling over 388,000 dives, and used unsupervised machine learning to identify the number of dive types, and categorize these dives. We calculated the maximum depth, duration and time spent at the bottom phase of each of each dive, and used the Calinski-Harabsz criterion to identify the number of clusters in the dives based on these three variables. The algorithm identified 3 types of dives overall. Comparing the dives employed during the day and night across foraging trips in the 4 islands, provided novel insights into the diversity of foraging behaviour in the Antarctic predator.

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Resource competition can explain coexistence and switching of collective states in fish shoals

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Animal aggregations are known to exhibit distinct collective forms (or 'states'), such as swarms or polarised groups. While these states can be recreated in simulations, empirical evidence for their adaptive value, and why groups might switch between them, is lacking. We show that responding to an ephemeral food stimulus is faster when fish shoals are in a disorganised, swarm state because of the reduced overlap in the visual fields of individuals. However, once social information becomes available, subsequent arrivals to the food are faster in more organised, polarised groups. By tracking individual identities, we reveal consistent inter-individual variation in the optimal group state. This conflict can explain switching between collective states, driven by competition for resources.

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Stochastic motor control of search behaviour in the model organism *C. elegans*

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Previous research on *C. elegans* search behaviour has been largely undertaken in short spatiotemporal scales and mainly focused on stereotyped turning behaviour. However, the structural organization of *C.elegans* search trajectories is more complex and spans a wide range of scales, so classic experiments are not able to explore generative mechanisms in whole detail. Here we expanded such classic scales up to 90 min and 24.5 mm2 in an effort to capture high-order trajectory dynamics and patterning. Our results show that *C. elegans* unfolds looping behaviour covering a wide range of sizes and in a time-ordered manner. Based on a microscopic (Langevin) stochastic model we are able to explain the observed variability in terms of speed and curvature motor control, and analyze how the movement of *C.elegans* departs from an elementary stochastic generative process, suggesting that neuromotor control of key movement variables at the microscopic scales modulate a program of (macroscopic) trajectory motifs, such as loops of multiple sizes and variability. We use these results to discuss the theoretical impact of the observed motor control and looping patterns under the perspective of sampling behaviour and search theory.

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The art of diplomacy in vocally negotiating barn owl siblings

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When rivalries are facing to compete for resources, the dynamic behavioural adjustments to the contestant's signalling can be as crucial as the average/maximum signal strength to prevail in competition. Unfortunately, the importance of the real-time signal modulation in conflicts resolution remains understudied, especially using an experimental approach. Here we developed a novel "automatic interactive playback" that directly interacts with a live individual in order to experimentally test the efficiency of different real-time adjustment strategies to become vocally dominant in nestling barn owls (*Tyto alba*) that negotiate for food when parents are absent. We found that to induce the withdrawal of a nestling from competition it is more efficient to match its call duration (i.e. mimicking the live nestling's change) and to mismatch its call rate (i.e. behave contrary to the live nestling's change). In addition, we showed that these strategies are the costliest because they require a larger investment of the playback (more and longer calls) than the less efficient ones, thus indicating the honesty of such behaviours. Our results therefore highlight the importance of real-time signalling adjustment in communication processes over resource competition and emphasize the power of using interactive playback settings to investigate the conflict resolution in animals.

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Cuckoldry in the family: Inclusive fitness benefits can mitigate costs of paternity losses

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Reproduction in many socially monogamous species is not always confined to the pair bond. Females may also mate with extra-pair males, and while this infidelity benefits the cuckolders it also incurs costs for the males that are pair-bonded to those females. Inclusive fitness gains that arise through genetic relatedness among reproducing individuals may dampen the costs that cuckolded males suffer, however this possibility has received scant attention to date. Here, we combine theoretical modeling with a genetic field study to ask whether 1) mating with close kin, or 2) allowing oneself to be cuckolded by close kin, can be adaptive for paired males when they are faced with rampant paternity losses. Using a socially monogamous wild fish, *Variabilichromis moorii*, we show that paired males possess a higher than expected level of relatedness to their cuckolders causing them to be measurably related to the extra-pair offspring in their nests. We also show that elevated relatedness between paired males and their cuckolders can be adaptive for both parties when competition for fertilizations is strong. Overall, our results show a long-postulated but largely untested -- and therefore under-appreciated -- effect of inclusive fitness on mating interactions; namely that cuckoldry by relatives can offset males' direct fitness losses with inclusive fitness gains, and this effect can be substantial in systems where paternity losses are frequent.

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Impacts of inter-group interactions on intra-group behavioral changes in Javan gibbons (*Hylobates moloch*)

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Agonistic inter-group interactions can cause individual costs such as physical injuries, increased physiological stress, and disrupted intra-group social relationship. Therefore, individuals employ various behavioral strategies to minimize the cost associated with the aggressive inter-group encounters. However, studies on impacts of inter-group encounters on intra-group behaviors are generally lacking, especially in species that live in small groups. We investigated behavioral strategies of territorial and pair-living Javan gibbons in response to inter-group aggression such as I) affiliative behaviors among pair-partners, II) changes in activity patterns and III) potential inter-group avoidance strategies, such as sleeping site selection. We observed 129 encounters among three habituated gibbon groups surrounded by four unhabituated groups in Gunung Halimun-Salak National Park from 2014 to 2016. Overall, we found no increase in the affiliative behaviors between pair-partners following the inter-group encounters. However, we found a decrease in grooming interactions after more aggressive encounter but not after lost encounters. During inter-group encounters gibbons significantly altered their activity budgets: they foraged and socialized less but stayed inactive and called more often. We also found that gibbons avoided inter-group encounters by sleeping farther away from the inter-group encounter location on days with more aggressive interactions. Our study indicates that between-group conflicts do not promote affiliative behavior in gibbon pairs, but provide evidences of changes in activities during encounter and inter-group avoidance through sleeping site selection in gibbons.

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Foraging as an evidence accumulation process

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The patch-leaving problem is a canonical foraging task, in which a forager must decide to leave a current resource in search for another. Theoretical work has derived optimal strategies for when to leave a patch, and experiments have tested for conditions where animals do or do not follow an optimal strategy. Nevertheless, models of patch-leaving decisions do not consider the imperfect and noisy sampling process through which an animal gathers information, and how this process is constrained by neurobiological mechanisms. We formulate an evidence accumulation model of patch-leaving decisions where the animal averages over noisy measurements to estimate the state of the current patch and the overall environment. We solve the model for conditions where foraging decisions are optimal and equivalent to the marginal value theorem, and perform simulations to analyze deviations from optimal when these conditions are not met. By adjusting the drift rate and decision threshold, the model can represent different 'strategies', for example an incremental, decremental, or counting strategy. These strategies yield identical decisions in the limiting case but differ in how patch residence times adapt when the foraging environment is uncertain. To describe sub-optimal decisions, we introduce an energy-dependent marginal utility function that predicts longer than optimal patch residence times when food is plentiful. Our model provides a quantitative connection between ecological models of foraging behavior and evidence accumulation models of decision making. Moreover, it provides a theoretical framework for potential experiments which seek to identify neural circuits underlying patch-leaving decisions.

Poster presentation abstracts

1

'Approach the danger!' Semantic modification in willow tit mobbing calls

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In human speech, words can be strung into larger compositional structures (phrases or sentences), which often provide modified meanings to listeners. Although combinations of meaningful vocal elements have been documented for several birds and nonhuman primates, little is known about how receivers comprehend semantic modification in combined vocal sequences. Here, I report the evidence that birds combine meaningful vocal elements to convey a modified message to receivers. Willow tits (*Poecile montanus*) use combinations of warning and recruitment calls when mobbing a predatory hawk. Playback experiments showed that receiver tits exhibit mobbing-like behaviours (i.e. making hops and flights with calling) when hearing these call sequences. In contrast, separated warning and recruitment calls cause birds to either flee to the cover or approach the sound source. These results indicate that willow tits recognize call sequences as a modified message ('approach the danger'), but not as two separated messages (i.e., 'flee' and 'approach'). These findings provide a novel example of the creation of modified meanings in animal vocal sequences.

A Generalised Multi-Segmented Model to Describe Swimming Kinematics in Fishes

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Undulatory body movements of fishes have evolved to be an effective propulsive method, inspiring many researchers attempts to quantify these complex biological mechanisms. Here, we propose a mathematical model and data processing pipeline to automatically describe the midline kinematics of fishes during steady swimming. Our model consists of a series of rigid segments of variable lengths, with each segment being able to pitch about their joint with their predecessor. We use data-driven approaches to estimate the variables of the model (e.g. number of segments and their lengths, and the amplitude and timing of each segment's movement) so that the difference between predicted and measured midlines is minimised. So far, we tested our approach by attempting to describe the midline kinematics of rainbow trout (*Oncorhynchus mykiss*, n = 2 fish, total body length L 15.5 and 23 cm) over a range of swimming speeds (1 L s-1 to 3 L s-1). Preliminary results from our initial investigation suggest that the model is able to describe the midline kinematics of trout with at least 90% accuracy, as measured by mean absolute error normalised by the maximum tail beat span. The ultimate goal of this research is to develop an analytical tool that can automatically generate midlines that are very similar to those of live fishes. In the future, our model can be used by biologists to evaluate different swimming styles, by roboticists to develop new control algorithms and game designers to generate realistic movements for their fish avatars.

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Achieving cohesive and mobile groups with limited number of neighbours

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Previous swarm research has clearly shown that simple rules of interactions among neighbours can lead to stable movement patterns at the group level, and for this there is no need for a centralized control strategy. To better understand the link between local interactions and emergent collective movements, we ask two questions: i) how many neighbours does each member need to take into account for a swarm to achieve a high performance (n)? and ii) how does n scale with group size (g)? To address these questions, we performed multi-agent simulations in a three-dimensional environment with obstacles. Each agent is programmed to have three behaviours agent/obstacle/tank avoidance, and alignment with and attraction to other agents. A winner-takes-all approach is used for decision making with avoidance and attraction having the highest and lowest priority, respectively. We used two metrics to evaluate the performance of the group; cohesion calculated based on the number of splits occurred within the group and mobility based on the displacement of the group. Our preliminary results suggest that there is a trade-off between cohesion and mobility; when n:g ratio is low, the swarm lacks cohesion but is highly mobile, and when n:g is high, the swarm is highly cohesive but stagnant. We hypothesise that there is an optimum n:g ratio which leads to highly cohesive and mobile swarms.

4

Acoustic environment affects hormonal level and behavior in mice

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Animals adjust their behavior adaptively under varying environmental conditions, which should require rapid endocrine response for sensory stimulation. However, little is known about whether and how environmental stimuli have an influence on physiology and behavior of animals. In this study, we investigated the influence of the acoustic environment on hormonal state and behavior in the C57BL/6J mouse. In experiment 1, we measured the corticosterone level of mice after 1-hour exposure to two acoustic stimuli: (i) rainforest sounds (n = 8) and (ii) no sounds (n = 8). We found that mice exposed to rainforest sounds showed a lower corticosterone level than those exposed to no sound. In experiment 2, we measured behavioral activities of mice in an open-field in combination with the playbacks of (i) rainforest sounds (n = 13), (ii) reversed rainforest sounds (n = 13), (iii) white noise (n = 12), or (iv) no sounds (n = 12). We found that behavioral activities of mice differed among the four treatments: mice exposed to reversed rainforest sounds showed the highest level of activity, following by those exposed to rainforest sounds, to no sounds, and to white noise. These results show that acoustic environments affect both hormonal state and exploratory behavior of the mice, emphasizing the importance of considering ambient sounds in environmental enrichment.

5

Age-dependent influences of general anaesthesia on the cognitive abilities of macaques

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Increasing life expectancy and advances in medicine are resulting in a growing number of elderly patients undergoing surgery under long-lasting general anaesthesia. Such long-term anaesthesia may particularly impact the cognitive abilities of aging humans (post-operative cognitive dysfunction, POCD) but until now, the underlying mechanisms remain unclear. The present study aimed to establish a non-human primate model for POCD by testing the physical and social cognitive abilities of young and old long-tailed macaques (*Macaca fascicularis*) before and after general anaesthesia (N = 13). Our study examined if general anaesthesia with isoflurane in the first part and with propofol in the second part of the study influenced cognitive abilities and if these effects were age-dependent. Statistical analysis did not reveal significant effects of age or anaesthetics on performance levels in physical and social cognitive tests which contradicts findings of cognitive impairment after general anaesthesia in humans. Further studies need to clarify whether the test battery may not be suited to detect and quantify impairments, or whether long-tailed macaques are generally less susceptible than humans to such cognitive impairments after general anaesthesia.

6

Are arboreal frugivores creating food patches for ground-dwelling fruit-eaters?

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Tropical rainforest ecosystems are enriched by a diverse set of complex interactions between plants and animals. Arboreal frugivores may play an important, and little studied role, as they create food patches for ground-dwelling animals. Arboreal frugivores regularly drop fruit from trees before they would naturally fall to ground, potentially facilitating sources of food for terrestrial species to exploit. If these food sources are important, we predict that terrestrial frugivores should eavesdrop on arboreal frugivores to maximise their feeding efficiency and alter their movement in response to cues and signals produced by arboreal frugivores. In this study, we test if interspecific transfer of information about food resources play a role in the structure and assembly of Neotropical frugivore communities on Barro Colorado Island, Panama. During an ecologically simple time-period when only one main tree species is fruiting, a combination of acoustic play-back experiments, remote camera-trap monitoring, and GPS tracking data is used to examine if terrestrial frugivores actively eavesdrop on signals and cues made by arboreal frugivores, are attracted by them, and adjust their food search in response. The preliminary results suggest that terrestrial frugivores are attracted, signifying that arboreal primates may play an important role in Neotropical rainforests. Primates are often the first species to be hunted and the loss of primates could affect food availability for terrestrial mammals, because primates drop partially consumed fruits, sometimes months prior to their availability on the ground when there is little else for terrestrial species to eat.

7

Camouflage in a dynamic world

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The environment plays a significant role in shaping the visibility of signals both to and from an organism. For example, against a static background movement is highly conspicuous, which favours staying still to optimise camouflage. However, backgrounds can also be highly dynamic, such as areas with wind-blown foliage or frequent changes in illumination. These dynamic features introduce irrelevant visual noise which could serve to mask motion signals. Two forms of illumination change - water caustics and dappled light - are of primary interest and represent dynamic aquatic and terrestrial environments respectively. Using an array of model organisms from both environments, we highlight the extent to which these dynamic features influence behaviour, perception and camouflage.

8

Cognition and fitness in wild grey mouse lemurs, *Microcebus murinus*

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The fact that neither all species nor all individuals within a given species exhibit the same, unlimited cognitive abilities indicates the existence of proximate constraints and evolutionary trade-offs involving the underlying traits. However, the magnitude and sources of inter-individual variation in cognitive abilities remain poorly known; primarily because only a few studies have linked variation in cognitive abilities to micro-evolutionary processes and fitness outcomes. We tested 90 wild grey mouse lemurs (*Microcebus murinus*) in four cognitive tests, a novel problem-solving, string-pulling and inhibitory control task and a spatial memory test, that showed high variation in the wild primate population. We investigated individual characteristics potentially influencing animals' performance, including sex, age, personality and energetic state, and linked cognitive abilities with monthly survival in the wild. We found that performance in one cognitive task was generally a weak predictor of performance in any other task, providing no evidence for the existence of a general factor explaining cognitive performance in wild grey mouse lemurs. Performance in problem solving efficiency was positively to longevity. However, performance in string-pulling and inhibitory control where negatively related to longevity, whereas performance in spatial memory was not linked to longevity. Hence, our results highlight the need to expand links between cognition and fitness within study species by investigating multiple cognitive abilities addressing fitness-related behaviours in different contexts and various fitness outcomes simultaneously. This will help to detect the complex relationships between cognition and fitness and broaden our understanding how cognition evolved

9

Determining hazel dormouse distribution at a reintroduction site using footprint tracks

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The hazel dormouse (*Muscardinus avellanarius*) relies on woodland habitat containing wide plant diversity and rarely comes to the ground to cross open spaces. For these reasons, the species has been severely affected by woodland fragmentation and changes in woodland management practices in the UK. Having been lost from over half of its UK range, a series of reintroductions have taken place. To ensure the long-term success of these reintroductions, it will be necessary to understand why some sites are colonised more readily than others, as well as understand the details of the preferred dormouse habitat.

A mixed semi-natural ancient woodland reintroduction site in Cheshire has, in recent years, been finding fewer dormice in nest boxes. We aim to understand the reasons behind this decline, including whether it is a reflection of a local population decline or is a result of local dispersal to more suitable habitat. Here, we use footprint tunnels to determine whether dormice are still present in the woodland and if so, where they are located. This will help to direct future research through understanding specific dormouse habitat preferences and the local distribution of other small mammal species, which may be a source of competition for dormice. It will also be used in planning for future hazel dormouse reintroductions at this site and others.

10

Development of chromatophore motor control in cuttlefish

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From the time of birth to the stage of reproductive maturity, animals experience a growth in body size. In order to survive through all stages of development, animals must undergo continuous behavioural adaptation. In coleoid cephalopods, one of the most important survival tactics is adaptive camouflage. Unique among animals, they are able to camouflage by dynamically controlling the sizes of the many chromatophores covering their entire skin. Juvenile common European cuttlefish (*Sepia officinalis*) experience dramatic body growth in the first few months of their lives (quadrupling in surface area in 3 months), during which new chromatophores are also emerge. Using video analysis techniques including convolutional neural network, optic flow and template matching, we tracked the activity of individual chromatophores of the same animals for up to 3 months, at 1-week interval. Crucially, the size of chromatophores are controlled by radial muscles that are directly innervated by motor neurons in the brain. Thus, this method not only serves as a quantitative measurement of a complex behaviour during development, but also provides a window into the neuronal remodelling underlying the adaptation of such behaviour, in a non-invasive manner. Here we present findings on the modification of motor control with regard to the physical changes brought about by the dynamic process of growth.

11

Do conservation translocations influence song diversity: New Zealand Saddleback, a model system.

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One of the most intriguing features of songbirds is in the formation of distinct, geographical song dialects - or cultures. Song learning from conspecifics is a crucial aspect of songbird ecology as song cultures can have important consequences for the survival and reproduction of individuals and potentially contribute to speciation through their influence on mate choice. That being said, conservation translocation procedures commonly measure their success on the preservation of genetic diversity and consequently the impacts of these practices on cultural processes goes largely overlooked. With growing evidence emphasising the importance of preserving socially transmitted song cultures, the conservation tactics employed at Tawharanui Nature Reserve, New Zealand for the North Island Saddleback / Tīeke (*Philesturnus rufusater*) provides us a unique case study.

To maximise song diversity, the group composition of Saddleback selected to be reintroduced into Tawharanui was composed of birds from three culturally distinct island populations. Our research intends to examine how the cultural evolution of the species is affected by simultaneously reintroducing culturally divergent populations into the same area. Indeed, this presents us with the ability to investigate how song dialects permeate through a fragmented landscape and to test the cultural processes that shape/drive the movement. Do increased cultural mutation rates following translocation cause new dialects to rapidly form? Have translocation efforts of the past caused rapid cultural contact barriers to form, thus impacting effective population size? Are there song learning biases? Exploring these questions and their results will have profound impacts on conservation management policies moving forward.

12

Ecological and evolutionary causes of phenotypic variation in a cooperatively breeding cichlid

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Cooperative breeding is a complex form of social group living, where individuals other than breeders help raising offspring. These subordinate helpers engage in care for eggs and juveniles, food provisioning, and territory maintenance and defence. Such helper investment is expected to be adjusted to the biotic and abiotic ecological conditions of the habitat, like varying predation risk or substrate quality. Ecological factors that are stable over several generations furthermore may lead to morphological adaptations, which may feed-back on the behaviour. The cooperatively breeding cichlid *Neolamprologus pulcher* inhabits a diverse set of ecologically distinct habitats in Lake Tanganyika, in which they express differences in social system and morphology. In this study, we investigate if such morphological variation can be explained by geographic distance or local adaptation to the respective ecological conditions. In order to measure morphological variation in the wild we conducted geometric morphometric analyses of wild caught individuals from eight ecologically distinct populations. We then raised F1 individuals from these populations under common garden conditions in order to disentangle plastic and genetically determined responses. We furthermore used microsatellite markers to analyse genetical differentiation between these eight populations. Results suggest morphological adaptation to predation risk and substrate quality that can neither be solely explained by plastic reactions to the environment, nor by genetic distance. These results indicate that phenotypic adjustment to the respective environment have a heritable component, which has the potential to feed-back on the social system of this cooperative breeder.

13

Fluctuating selection on spatial abilities over multiple years in a population of pheasants

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Exaggerated cognitive abilities presumably arise because they bring fitness benefits to individuals expressing them. For example, in species where one sex moves further, we expect the fitness of that sex will be more strongly correlated to their spatial ability. Female pheasants disperse further than males so we predicted they would show stronger relationships between spatial ability and survival than males. We assayed the spatial memories of ~200 pheasant (*Phasianus colchicus*) chicks over three years (2015-2017). In 2015, as predicted, females dispersed further and those that had exhibited better spatial memory were more likely to survive, but this did not predict male survival. In contrast, in 2016 although females still dispersed further, the result was reversed: males with better spatial memory were more likely to survive, but this did not predict female survival. In 2017, we found no relationships in either sex. Our results can be interpreted in two ways. Either annually fluctuating selection pressures act on sex differences in spatial ability, necessitating long term studies of fitness outcomes to understand evolution of cognitive abilities. Alternatively, spurious relationships may be detected, even with reasonable sample sizes and clear a priori hypotheses, necessitating extensive replications before we can confirm how selection may act on cognitive traits.

14

Gibbon's perspective-taking abilities in a competitive task

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The capacity to follow others gaze is a fundamental socio-cognitive ability. However, the psychological mechanisms underlying this capacity might vary between species. In its simplest form, gaze following consists of an automatic response to others' gaze. A more complex variety involves a mentalistic understanding of the content of others' gazes. This second variety has been mainly found in a reduced number of primate species. In our study we explore whether a largely unstudied group of primates, the gibbons, are capable of understanding the content of others gaze. For this purpose, we establish two paradigms in which a human experimenter induces a competitive relationship by preventing the ape to retrieve one of two rewards lying in front of them. To succeed, the ape should infer - based on different cues - the intentions of the experimenter. In study one the experimenter positions himself between the two rewards and orients his body towards one. In study two, the experimenter orients his body to the center of the testing room while only orienting his head towards one of the two rewards. At the same time, he either keeps his eyes open or close. In both studies the apes should retrieve the reward the experimenter does not face. However, in study two the ape should rely on more subtle cues such as the eyes to infer what the experimenter really sees. Overall, we found that gibbons succeeded in a majority of trials but only took into account gross cues such as body or head orientation.

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How does social influence affect performance on a human recognition task in wild urban-living cockatoos (*Cacatua galerita*)?

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Human induced rapid environmental change causes not only destruction but also the creation of new opportunities. Some species are better at adapting and surviving in these new habitats than others. Previous work has suggested that cognitive skills could provide an advantage when facing those novel challenges and opportunities. For instance, animals in urban areas live in close proximity to humans. However, people vary considerably in their behaviour towards animals. Therefore, it would be advantageous for urban living animals to learn to distinguish between persons in order to response appropriately towards specific humans (e.g. flight or approach). In addition to individual learning, social information from conspecifics could play a potentially important role in this decision-making. I investigated these questions in the highly social and cognitively-complex sulphur-crested cockatoo (*Cacatua galerita*), a successful invader of urban environments across the Austral-Pacific. The native population of Sulphur-crested (S-C) cockatoos in the Sydney region of Australia, approach people in order to get desirable food, but are also persecuted, for example as crop raiders. Using this population, I first tested whether S-C cockatoos are able to learn to distinguish between individual humans over the course of 14 session over 7 days of a two-choice experiment, where 76 individually-marked birds were randomly assigned to be only fed by one of two people. Second, by manipulating whether how birds were assigned across the two provisioners, I asked whether social influence plays a role individual decision-making; specifically, whether conflicting personal and public information interferes with this learning process.

16

How the social environment affects competitive signalling by female house mice

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Odour signals used in competition between male mammals are well studied in the context of sexual selection. By contrast, relatively little is known about the use of odour signals in competitive interactions between females, and the conditions that influence female signalling effort. House mice (*Mus musculus domesticus*) are an ideal study species to investigate this. Female house mice live in complex social environments, and previous evidence suggests that urine marking plays an important role in their communication and competitive interactions. Also, the urine of female house mice contains major urinary proteins (MUPs), which can be expressed at relatively high concentrations under naturalistic conditions. Here we present preliminary results from a long-term experiment aimed at understanding how the social environment influences competitive behaviours of female house mice. We manipulated levels of resource competition and relatedness within social groups under controlled naturalistic conditions, performed behavioural assays to record scent marking behaviours, and monitored urinary MUP concentrations. Our study reveals how female house mice flexibly adjust competitive signalling in relation to local resource competition and relatedness of competitors within their social group. This study adds to the growing evidence that female competition is an overlooked but important selection pressure regulating the complex social lives of mammals.

17

Influence of conflict during consensus decision making in ant colonies

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Social systems can take consensus decisions in a decentralized manner. There are numerous theoretical and empirical studies aimed at understanding the algorithms behind consensus decisions, modes of interaction between individuals, and individual roles in a collective. An interesting question is how conflicting interests are managed when individuals become part of a group. The two commonly provided explanations are; (1) what appears as cooperation is, in fact, individuals furthering their own, often conflicting, interests and possibly yielding sub-optimal collective performance. (2) Due to the increased genetic relatedness between the group members, in eusocial systems, the effect of conflict is negligible. In this study, we aim to quantify the influence of conflict on consensus decisions. Information conflict is induced in an ant colony performing collective behavior. House-hunting experiments were performed in the *Componotus sanctus* colonies reared in lab. The nature and strength of conflict between the individuals are varied using automatic gate control system developed in our lab coupled with individual barcoding of ants. Preliminary results show that consensus decisions are influenced by varying strength of conflict.

Methods for analysing high-resolution collective movement data from the wild

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A wide range of taxa, from bacteria to birds and mammals, exhibit collective behaviour and display fascinating patterns. A novel aspect of emergent properties of collective behaviour is that they are more than just an aggregation of individuals's actions. Most studies on emergent properties of collective behaviour are conducted in controlled laboratory conditions. In natural settings, however, habitat varies in terms of resource distribution, availability of hiding places and substrate for movement. However, very few empirical studies have recorded such fine-scale interactions in animal groups in their natural habitat. One reason for the dearth of such studies might be due to the difficulty in capturing multiple spatial interactions at any single time instant. Recent advances in techniques of aerial imagery allow us to observe and record such interactions.

We are studying the spatial dynamics of blackbuck (*Antilope cervicapra*) herds using high-resolution aerial imagery. We have recorded fine-scale interactions within blackbuck herds using multiple 15-minute aerial videos. In the first part of our work, we investigate which image-processing methods are most appropriate to analyze videographic data of fine-scale movement and interactions. We compare three computer vision techniques, motion detection, colour segmentation, and convolutional neural networks, to get individuals' trajectories in various datasets. Our comparison of the techniques suggests that for blackbuck videos (highly heterogeneous background and group composition) convolutional neural networks provide the most accurate results. We provide a framework to implement customize and implement track multiple objects in a heterogeneous environment.

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Quantity discrimination and biases in giraffes (*Giraffa camelopardalis*)

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The evolutionary origins of “number sense” are highly debated, with a lot of research going on. Here we tested giraffes’ ability to discriminate food quantities under different conditions. We tested six giraffes at the Barcelona and Leipzig Zoos by presenting them with two sets of carrot pieces. Depending on the task, we first tested them with different quantities of the same food (Experiment 1), and then we varied the size of the rewards (Experiment 2) and the distance between the elements of each array (Experiment 3). In Experiment 1, giraffes performed like other mammal species, showing a significant preference for the set with more pieces of food, and showing a consistently ratio-dependent performance, suggesting that they rely on an Approximate Number System. In Experiment 2, we tested whether giraffes preferentially rely on size rather than number of stimuli, when selecting the larger quantity of food, but giraffes showed no significant preference. Finally, in Experiment 3 we investigated if giraffes prefer sparse over dense arrangements of food pieces. Giraffes showed a consistent bias towards sparse arrays, which may be linked to their foraging style in the wild. Overall, these results provide a first picture of giraffes’ ability to discriminate quantities, which may also be useful to better understand the behavior and ecology of wild and captive giraffes.

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Motion patterns, predictability and predation responses within a wild, freely moving fish school

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The collective motion of fish schools is well understood on a mechanistic level, however, only few studies can link their findings to individual fitness instead of group properties. Here, a chichlid fish species, *Lamprologus callipterus*, was used as a model system to analyze collective motion patterns in natural environments with respect to individual behavior and interspecific interactions of potential risk. A combination of Structure-from-Motion scene reconstruction and high-resolution animal tracking via deep neural networks allowed detailed trajectory analyses via behavioral decomposition. A time-frequency representation of the animals' motion kinematics via continuous wavelet transformation resulted in a high-dimensional description of continuous behavior, including temporal information. On this basis, a stochastic neighbor embedding was used to reduce the dimensionality of motion data, allowing subsequent clustering. Hence, unsupervised labeling of group states and individual behavior was possible and enabled further behavioral analyses. The key findings suggest that the motion behaviors of individuals within schools of *L. callipterus* are synchronized, even under precarious environmental scenarios such as predation. In contrast, the predictability of individual behavior transitions was found to be reduced under these risky circumstances in comparison to a high baseline predictability. This indicates a behavioral adaptation to predation risk on the individual level that is potentially linked to central hypotheses concerning the evolution of collective systems such as the predator confusion hypothesis.

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Bridging the gap between lab and field

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Although methods for tracking animals underwater exist, they frequently involve costly infrastructure investment, or capture and manipulation of animals to affix or implant tags. These practical concerns limit the taxonomic coverage of aquatic movement ecology studies and implementation in areas where high infrastructure investment is impossible. Here we present a method based on deep-learning and structure-from-motion, with which we can accurately determine the 3D location of animals, the structure of the environment in which they are moving. Further behavioural decomposition of the body position and contour of animals subsequently allow quantifying the behavioural states of each interacting animal. This approach can be used with minimal infrastructure and without confining animals to to a fixed area, or capturing and interfering with them in any way. With this approach, we are able to track single individuals (Conger Eel, *Conger oceanus*), small heterospecific groups (*Mullus surmuletus*, *Diplodus sp.*), and schools of animals (*Tanganyikan cichlids Lamprologus callipterus*) in freshwater and marine systems, and in habitats ranging in environmental complexity. Positional information was highly accurate, with errors as low as 1.67% of body length. Tracking data was embedded in 3D environmental models that could be used to examine collective decision making, obstacle avoidance, and visual connectivity of groups. By analyzing body contour and position, we were also able to use unsupervised classification to quantify the kinematic behavioural states of each animal. The proposed framework allows us to understand animal behaviour in aquatic systems at an unprecedented resolution and a fraction of the cost of established methodologies, with minimal domain expertise at the data acquisition or analysis phase required. Implementing this method, research can be conducted in a wide range of field contexts to collect laboratory standard data, vastly expanding both the taxonomic and environmental coverage of quantitative animal movement analysis with a low-cost, open-source solution.

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Multisensory integration of information requires more than one single trial in garden ants

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Several studies showed that ants learn and integrate information from different sensory modalities and that the combined presence of more than one type of information enhances their performance. Such evidence supports the idea of multisensory integration as an optimal strategy for ants to retain information useful to address their own behaviour. Multisensory integration is at the basis of self-experienced memories, which require the integration of information about what-where-which a certain event happened to that individual. Here we investigated whether ants *Lasius niger* can learn what-where-which components in a foraging task. Individual ants where first placed in a Y-maze in which they were exposed to different odours (lemon vs. rosemary - 'what'), direction (left vs. right - 'where') and wall colours (blue vs. yellow - 'which'). Odour information was predictive of the reward by itself, while the other two information were predictive only when combined (e.g. if blue, then go left). After 12 visits, ants where tested by making the what component uninformative (the same odour was present on both arms). In a second experiment, we tested whether ants could learn the what-where-which components within a single experience, using the same maze as in the first experiment but presented only once within a non-relevant training (a single runway). Our results showed that ants succeed in integrating the what-where-which components following repeated experience (Exp.1) but not following a single trial learning (Exp.2). Considering the task did not involve any aversive or unusual event, ants' abilities of multisensory associative learning in a foraging situation appear remarkable.

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Nest Population and Excavation Dynamics in the carpenter ant *Camponotus fellah*

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Ants construct their nests according to colony size, however, relationship dynamics between population and nest volume are unclear. We conducted a six-month study in which we followed nest excavation by *Camponotus fellah* in sand-filled 2D vertical nests, from founding queens to mature colonies. Colony and nest development were tracked by simultaneous regular measurement of nest architecture along with colony size and spatial distribution. We found that the ants' density in the excavated nest was maintained within a certain range throughout nest development. Moreover, population increases were generally followed, with some time lag, by significant digging that returned density to its previous level, suggesting the colony regulates nest density. We also found digging to be positively correlated with population growth in the preceding timeframe of seven weeks. Based on these findings, two models are proposed for digging rate. In the first, the colony actively regulates density by responding with accelerated digging to population increases. The model assumes the colony assesses ant density in the nest, however, direct regulation seems unlikely as ants tend to aggregate in specific chambers. The second model does not require the ants to actively sense density or interact, and claims that digging rates depend solely on population growth at a preceding timeframe. This model also supports interpretations based on workers' age and task allocation. To test the models and better understand density regulation, we plan to further analyze collected data by focusing on ants' spatial distribution within different chambers and tunnels, and their responses to collapse events.

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Of mongooses and men: how traffic noise differentially affects a social mammal.

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Road networks are a major feature of our global landscape and increasingly recognised for the damage they can inflict on wildlife, as a result of collisions, habitat segmentation, disturbance and pollution. In the last decade, it has become increasingly clear that traffic noise can have a negative impact on animals, but little is known about whether variation in traffic noise characteristics affect behavioural responses. This study experimentally investigated the effects of two types of traffic noise-continuous and intermittent-on the behaviour of dwarf mongooses (*Helogale parvula*) in a wild habituated population. Mongooses showed greater vigilance (increased scan frequency, proportion of time vigilant and time acting as a sentinel), and were more likely to move foraging patches, during traffic-noise playback compared to ambient-sound playback. Even after playback ended, individuals continued to show elevated vigilance compared to in control conditions. However, there was no significant difference between continuous and intermittent traffic noise. A second playback experiment, conducted at the sleeping burrow first thing in the morning, found that continuous traffic noise delayed group emergence and departure to forage. If such noise effects persisted and individuals could not compensate for lost foraging time, there could be detrimental consequences to condition and survival.

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Physiological costs of reproduction in female Assamese macaques (*Macaca assamensis*)

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Reproduction is a critical process in mammals and typically triggers pronounced physiological changes in females as they bear the costs of gestation and lactation. While it is established that those physiological costs of females' reproduction cause both an energy deficit and a stress response (through a rise in glucocorticoids (GCs) level), relatively little is known about how fluctuations in food availability, potentially leading to variation in a female's energy balance, impact a female's ability to reproduce and how the physiological costs are distributed over the course of reproduction. Using ecological (monthly phenology records), behavioral (~3,000 focal hours) and physiological (1080 urine samples) data collected on 45 adult female Assamese macaques across 13 months at their natural habitat in Thailand, we investigate the physiological costs of female reproduction under seasonally occurring nutritional constraints. We use urinary C-Peptide (uCP) as a non-invasive marker of energy balance, and urinary GCs as a more general measure of physiological stress and aim at disentangling how these two physiological markers are impacted by reproduction. As data analysis is currently ongoing, preliminary results will be presented on variation of uCP and GCs in relation to overall food abundance in the habitat and individual female reproductive status.

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Population Size and Turnover Increase Cultural Selection for Efficiency

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Socially transmitted behaviors are hypothesized to be under cultural selection for adaptive benefit to the organism, with iterated transmission between individuals and the feedback between social learning and innovation generating greater increases in efficiency. While well-studied in humans, there is a lack of experimental evidence for this process in other species. Previous studies in great tits (*Parus major*) have shown that when birds are presented with experimentally presented foraging puzzles, the solving technique will socially transmit with a conformist bias, establishing as new local tradition. Here, we test whether 1) such established traditions will improve in efficiency over time, and 2) whether innovation and subsequent cultural selection is affected by demographic factors such as population size and turnover rate. An automated sliding door foraging puzzle with two solutions of differing efficiency was presented to captive micro-societies of wild-caught great tits, with one demonstrator in each population initially trained to the inefficient solution. Populations were followed over 5 weeks, with population size and population turnover manipulated in a two-way factorial design. Preliminary results suggest that turnover facilitates selection for efficient behaviors: immigrants were more likely to innovate or switch to the new efficient behavior, and a conformist bias did not prevent its emergence or spread. This process also occurred faster in the larger population, although more replications are needed to confirm this. Our results contribute empirical support for the presence of cultural selection for adaptive benefit in animals and highlight the importance of social conditions for cultural outcomes.

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Seasonal Variation in Home Range and Sleeping Site Use in Hamadryas Baboons

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Hamadryas baboons are characterized by a four-tiered multi-level social system, which may cleave and coalesce over time in response to seasonality and other ecological factors. Here we explore ranging patterns, sleeping site use, and separation of bands over time in a population of hamadryas baboons in Ethiopia. Between 2015 and 2018, 7 adult males from the same band were outfitted with satellite-linked GPS collars and tracked for periods between 8 and 12 months. We calculated approximate home ranges for the band during each study period using GPS fixes recorded by the satellite collars. We used fixes collected at night to determine sleeping site locations and band separation frequency. The MCP home range for our study group was 115.62 km2 from July 2015 to March 2016 (n = 2350 GPS fixes), 104.83 km2 from October 2016 to October 2017 (n = 1367 GPS fixes), and 96.95 km2 from July 2018 to March 2019 (n = 2195 GPS fixes). There were significant differences in home range size between months, with May, August, and September being significantly larger than average ($p = 0.01$). Males from the same band slept at different sites 27.1% of all recorded nights (n = 170) in 2015 - 2016, 20% in 2016 - 2017 (n = 336), and 29.7% in 2018 - 2019 (n = 185), with more separations occurring during the transition to the dry season. This study uncovers previously unknown home range and sleeping site use variation in hamadryas baboons, highlighting the adaptive benefits of their multi-level social system.

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Serial reversal learning in the young domestic chick

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Intelligence can be broadly defined as a property of an individual to interact with its environment, the ability to profit with respect to some objective and to adapt to new situations. Such definition implies that a wide variety of animal species do exhibit intelligent behaviour. In particular, convincing evidence has been accumulating that cognitive abilities of some avian species are comparable to those of primates. However, inter-species variability and the use of different tasks has made it difficult to measure and quantitatively compare birds' performance. To overcome the species-specific constrains such as differences in motor, visual and other systems, the use of serial reversal learning task has been put forward. This task requires inhibitory and excitatory conditioning, the ability to inhibit the previous responses and to learn the general rule which makes it suitable for measuring the construct of behavioural flexibility with a real strength in a comparative perspective. Here in the attempt to validate this paradigm in young chicks, we tested 6 male domestic chicks (*Gallus gallus*) from 3 to 20 days old in a series up to 10 reversals. Preliminary data suggest that chicks make more errors in the first reversals and reach a very low error rate in the last two, 9th and 10th reversals. Overall, in spite of their early age, domestic chicks seem to outperform other avian species, such as adult pigeons and even adult corvids, which data are reported in previous literature.

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Soundscapes on islands and mainland: differences and influences on bird acoustic communication strategies

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On islands, species richness is reduced and interspecific competition relaxed in relation to the mainland, allowing species to use broader ecological niches. These factors can also affect communication and in particular acoustic signalling and niches. (1) To determine to which extent islands present reduced acoustic richness and fewer constraints for singing species, we compared two pairs of insular and continental soundscapes: one in a temperate zone, the other in the tropics (Cameroun and Sao tome). We found ambient noise was louder in the tropics and occupied a wider frequency range, especially on the mainland. (2) We then compared bird way of singing on islands and mainland. In the more crowed and noisy tropical mainland soundscape, species acoustically avoided more each other when compared to the three other communities (higher acoustic turnover, less overlap in time and in frequency between species composing the community). (3) To determine whether acoustic niche was modified on islands compare to mainland, we last worked on 24 species; 12 endemic insular species and their closest mainland relatives, breeding in the above temperate and tropical habitats. We found that insular species spend more time singing alone, sing with less species and that their songs span broader frequency ranges than their mainland counterparts (especially in the tropics). Overall, this study shows that soundscapes impose less constraints on singing species on islands than on the mainland and in tropical than temperate regions. Additionally, it suggests a link between the level of acoustic niche partitioning, frequency ranges and species interferences

Structure and associations within Grevy's and Plains zebra herds during a disturbance

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Social animals living in herds form often specific associations and structures. Analyzing the relationships between individuals within groups and the spatial distribution of groups can reveal how subgroups may affect the herd's ability to detect and respond to disturbances. In our research we focus on the structures and associations of zebras living in herds before, during and after a disturbance. Here we will compare association patterns between two species which use different social organization systems, namely harems versus fission-fusion societies, and investigate their reactions to a disturbance. We used drones to observe wild zebra herds in Laikipia, Kenia, before and after a disturbance caused by us approaching them by foot.

We used deep learning algorithms to extract locations and postures of each individual from our drone footage. 3D habitat maps were constructed to account for the impact of vegetation structures on the zebras' movement and association patterns. Using various metrics, we conducted social network analyses, to detect consistent subgroups and associations between individuals and to investigate the effects of social structure on collective response to disturbances.

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The Evolution of Stress-Induced Social Learning Strategies

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It is widely accepted that indiscriminate social learning can be maladaptive, and animals actively pursue adaptive social learning strategies in response to different social and environmental cues. Learning from or imitating parents (vertical social learning) is one way offspring can acquire adaptive, socially-learned behaviors. However, learning from non-parents (oblique social learning) may be preferable to vertical learning, especially in rapidly-changing environments (McElreath & Strimling 2008). Recent experimental studies in birds have shown that internal cues, such as stress, can also favor oblique over vertical learning. Hormone-induced stress may be a cue juvenile zebra finch use to adjust their social learning strategies adaptively (Farine et al. 2015, Boogert et al. 2018), with stressed individuals learning more often from non-parents and non-stressed individuals learning from parents. However, questions remain over whether this effect is driven by an adaptive, condition-dependent social learning strategy on the part of juveniles, or whether parents are simply avoiding their stressed offspring resulting in more oblique learning by default. To help clarify this issue, we present a stage-structured, condition-dependent social learning model that explores the evolution of stress-induced social learning strategies under varying rates of innovation and environmental change. We show that learning obliquely when stressed and vertically when non-stressed is often an adaptive social learning strategy, able to invade and evolve in populations as long as there is a sufficient fecundity advantage associated with adaptive behavior, the environment is reasonably stable, and innovation (i.e. successful individual learning) is sufficiently difficult. Our results provide confirming theoretical evidence that stress can trigger adaptive switching from vertical to oblique social learning.

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Serial Reversal Learning in Nectar-Feeding Bats: A Field Study

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Animals are constantly facing changing environments and thus need to modify their behaviour in response to change. This raises the idea that animals can learn, not merely simple associations between stimulus and reward, but can also ‘learn to learn’, i.e., learn general rules that dictate foraging behaviour in many contexts. The serial reversal learning task is widely used as a way to explore this ability. Animals discriminate between a pair of stimuli until a criterion is reached, and then the reinforcement contingencies of the stimuli are reversed. This can be repeated several times, and it is thus also a way of examining animals’ behavioural flexibility. We conducted field experiments with a species of nectar-drinking bat, *Glossophaga commissarisi*, to examine their behaviour in the serial reversal learning task in La Selva Biological Station, Costa Rica. We show that the bats learn the task rapidly, and though they do not quite reach the optimum rule of one error per reversal, come very close to it. We show also that, similar to bumblebees, their errors are almost entirely due to perseveration and not anticipation, and there is a slight increase in error rate in the final trials.

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Vocal individuality of Long-eared owl (*Asio otus*)

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Nowadays, individual vocal variability could be used for acoustic monitoring of individuals. Owls seems to be a great model species for acoustic monitoring research. They are nocturnal animals with high developed vocal territorial behaviour. Recording at night provides high quality recordings with minimum masking birds and urban noise. Contrary to passerines, owls have a simple and stable vocalization in time, therefore the temporal stability could allow long-term monitoring of individuals.

In this study we examined vocal individuality of Long-eared owls (*Asio otus*) within each season 2018 and 2019 and the comparison between them.

We recorded spontaneous hooting of an urban population of Long-eared owls in České Budějovice, The Czech Republic, from January to April during two following seasons 2018 (4 males, 6 females) and 2019 (7 males, 6 females). We used Marantz recorder and directional microphone Sennheiser ME67. We were recording as close to the vocalizing owls as possible (3-5 m distance), to get high quality recordings.

These recordings were analysed by using Avisoft SASLab Pro - an automatic parameter measurement function. We measured general vocal parameters: one temporal (duration) and six frequency (minimum, maximum and peak frequency, 25%, 50% and 75% quartiles of the spectrum) of single hoots. Due to very simple shape of single hoots, we measured frequency parameters 4 times: at the beginning, the centre and the end of the hoot as well as their measurement on the mean spectrum of entire element.

Statistical analysis and data visualization were done in R Project. LDA provide individual differences even for the measurement on the mean spectrum of entire element.

We found vocal individuality of Long-eared owl's hooting based on the general vocal characteristics.

Water-crossing behavior of red kites

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Soaring birds are usually reluctant to fly over large water bodies due to the lack of ascending air currents (uplifts). Aerial uplifts reduce the energetic cost of flight allowing to use soaring-gliding flight. Weak or absent uplifts require the use of powered flight, with exorbitant energetic costs for large species; the costs of powered flight proportionally increase with size and weight. Therefore, extended use of powered flight can be exhausting to a point where larger bird species risk drowning while crossing water bodies. As a consequence many species, particularly the large soaring raptors, take long over-land detours avoiding e.g. the open sea. Red kites (*Milvus milvus*) have a plastic flight behavior. Although they usually take advantage of uplifts, they can also perform long bouts of powered flight. On long journeys red kites usually prefer to take over-land detours, but occasionally are observed to fly over water covering distances of up to 410Km over 12h of continuous flight. We found that birds crossing the Adriatic Sea in autumn choose a route with low level of head winds, whereas when crossing in spring preferred tail winds. Nevertheless overall weather conditions on the crossing days was not different to any day within the migration season or outside it. Therefore it seems that the Adriatic Sea has mostly equally good conditions for the red kites to cross. In the future, higher resolution tracking GPS and acceleration data will shed more light on the cost of transport in red kites while crossing large water masses.

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A New Non-Invasive Method for Population Monitoring

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Rapid Evaporative Ionisation Mass Spectrometry (REIMS) is a new way of analysing biological material by a very simple treatment. A diathermy electrode is used to burn biological material and generates an aerosol that is highly information rich. REIMS is fast, non-invasive and requires no sample preparation. We have investigated the potential of REIMS to be used as a non-invasive method for monitoring mammals, using faeces as the biological source. We have shown that discrimination between different species is readily achievable in both wild and laboratory species. Changing the diets of house mice in the laboratory did not affect their ability to be classified. The aim of this study is to explore the extent to which REIMS can be used to discriminate donor sex, maturity or genotype. Preliminary analyses have been completed using laboratory strains (BALB/c, BALB/k, ICR(CD-1) and C57BL6) of house mice (*Mus musculus domesticus*) under uniform conditions. Five faecal pellets were burned for 170 individuals and the spectra were analysed by Random Forests using Rstudio within R. The accuracies of assigning faecal pellets to the correct sex and age class were > 80%, suggesting that REIMS has the potential to identify sex and age from faecal material. REIMS could provide a new approach to the analysis of faecal material which will lead to a faster and simpler method for population monitoring that requires no interaction with individuals and therefore increase animal welfare.

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A simple rule connects mechanistic and evolutionary models of foraging behavior in *Caenorhabditis elegans*

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An integrative view of behavioral ecology requires connecting different levels of description, from the genetic and neural underpinnings of behavior to its evolutionary consequences. The nematode *C. elegans* offers an opportunity to achieve this aim, being well studied at the level of genetics, development and neuroscience, as well as at the level of its elementary behaviors (i.e. its immediate response to a chemical gradient). Comparatively, we know less about how these elementary behaviors combine to produce the complex outcomes that determine fitness (i.e. finding a profitable food patch in a complex environment). As a first step to fill this gap, we have characterized *C. elegans* distribution across food patches of different qualities. We find a strikingly simple result: the ratio of the number of worms in any two food patches is equal to the ratio of the densities of the two patches. This result holds regardless of the absolute density of the food patches (across two orders of magnitude) and of the number of patches present in the environment -- a robustness that suggests simple underlying principles. From the evolutionary viewpoint, our results match the Ideal Free Distribution (predicted by game theory as the evolutionary stable strategy when animals compete for food). From the mechanistic viewpoint, we find that patch-leaving behavior is the dominant factor, with other factors such as chemotaxis and memory having an almost negligible impact on the observed distribution. These results therefore connect large-scale patterns predicted by evolutionary theory with the behavioral mechanisms leading to them.

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Adult contributions to pup care in dwarf mongooses

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Alloparental care (the provision of care to offspring by adults other than the parents) is widespread in social vertebrates. However, there is much unexplained variation in the contributions of different group members to these helping activities. Dwarf mongooses (*Helogale parvula*) live in groups of 5 to 30 individuals, consisting of a dominant breeding pair and subordinate adult helpers of both sexes. All adults contribute to babysitting (supervision of young when the group has left to forage), and to the feeding, movement and grooming of young. We used detailed observations from six wild but habituated dwarf mongoose groups to examine whether factors such as sex, dominance status and age influence variation in alloparental care. Preliminary analyses suggest that there is no variation between males and females in pup investment however adult dominance status and age do influence the level of contributions to different care activities. Our findings will contribute to the rich literature on cooperation, parental care and social living.

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Anxiety as a personality trait in zebrafish, *Danio rerio*

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The term 'personality' has been used to describe behavioural variations that are consistent over time and context. There has been much recent interest in these traits and their fitness consequences. At least some of these traits appear to be genetically determined but little is known about how these traits are controlled. Here, I investigate one personality trait, anxiety, in the zebrafish, *Danio rerio*. Three different tests were used to assess anxiety: novel tank diving test, open field test, and light dark test. The repeatability of these behaviours was assessed and the relationship between the different measures of anxiety was determined using PCA. These analyses showed that individuals varied in their level of anxiety but that some tests were more robust than others. This work will increase our knowledge of how this personality trait is controlled and should increase our understanding of how and why variable traits co- exist in populations.

Application of image processing to quantify self-grooming behavior of a prawn, *Macrobrachium lamarrei*

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Self-grooming is a neuro-phenotypic behavior in both invertebrates and vertebrates. Grooming has been established as a behavioral biomarker in assessment of stress and several neurotic disorders. Our target is to establish this behaviour as a marker of sensitivity in aquatic invertebrates.

Macrobrachium lamarrei (Arthropoda: Crustacea: Decapoda), is a commonly found native freshwater prawn species from India and adjacent countries and is abundant in most of the freshwater bodies. Self-grooming is a robust behavior in this species, which involves efficient use of the first and fifth thoracic appendages to clean different body parts. Microscopic analysis indicated adaptive modifications on the surface of the grooming appendages. Detailed assessment revealed a complex patterning of the entire self-grooming activity. The organism takes prominent postures of the body and grooming appendages to clean different parts of the body. Depending on the postures, we have classified the grooming activity in two major groups; anterior and posterior body grooming.

We have used video-based tracking system for identification and accurate quantification of self-grooming behavior in this semi-transparent prawn model. The method of image processing technique has been applied to quantify self-grooming in terms of time spent for each activity. We used a high resolution video camera to record the behavior frontally. A pilot recording of self-grooming was done in two different aquatic conditions (clean water and dirty water) where results show significant difference in grooming activity. Our ultimate target is to use this software for evaluation of stress-induced alteration in self-grooming by invertebrates.

Arctic avian predators follow the northern progression of snow melt during spring migration

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How and to what degree animals adjust movement to environmental conditions is a key question in ecology. Species breeding in the same environment can exhibit contrasting movement strategies due to the predictability of resources. Migratory species, for example, can display irruptive (facultative) or regular (obligate) movement strategies as a proximate response to differences in the availability of resources. In the Arctic resources are limited by snow, therefore arctic breeders might follow the northern progression of snowmelt during spring migration to optimize arrival time. The literature on this topic is scarce and the process of decision-making during migration as a response to snow conditions is largely unexplored. Based on large-scale Argos and GPS movement data, we compared movement decisions among three keystone arctic species, representing a gradient from an irruptive to a mixed to a regular migration strategy (the snowy owl, the rough-legged buzzard and the peregrine falcon respectively). Arctic migrants followed the northern progression of snowmelt during spring migration. However, the irruptive and mixed migrants adjusted their movement decisions more tightly to snowmelt than the regular migrants. Rapid environmental change is expected to shape snow patterns and consequently movement decisions of arctic migrants. Such changing conditions would affect the regular migrants most, resulting in a phenological mismatch. In contrast, irruptive and mixed migrants would adapt more easily. Considering the global climatic changes that the Arctic is undergoing, we expect altered movement decisions to shape movement strategies with cascading effects through the entire ecosystem.

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Behavior-based automatic measurement of happiness in both animals as well as humans

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One of the biggest challenges when studying welfare is answering the seemingly simple question: how happy are you? And yet, at the moment, the best tool at our disposal is self-reported surveys that ask exactly that. These surveys are not only inaccurate but they are of no use when dealing with non-verbal individuals such as babies, pets, or farm animals. Instead, we propose a tool that uses high-dimensional behavioral data to measure personal wellbeing in both animals and humans. Our machine-learning based approach quantifies happiness automatically, continuously, objectively, and in real-time. The uniqueness of our model comes from recognizing that happiness means different things for different individuals. What might be a joyful event for an extravert, like attending a crowded party, might leave an introvert feeling miserable. Happiness is really a personal thing and therefore strongly depends on our personality as well as our temperament. This is true for people as it is for animals.

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Behavioral and neural correlates of Hide & Seek in rats

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Evolutionary, cognitive and neural underpinnings of mammalian play are not yet fully elucidated. We played hide & seek -an elaborate role-play-game- with rats. Animals did not receive food rewards, but were engaged in playful interactions after finding or being found. All rats acquired the game. Playing the role of the seeker, rats systematically searched for the experimenter in a large 30 m2-room. Rats guided searches by visual cues and memories of past hiding locations. When hiding, rats preferred non-transparent over transparent enclosures. Animals were highly vocal at trial beginnings, when finding the experimenter, during playful interactions and when being returned for a new trial, but were silent during hiding. Rats appeared to enjoy the game itself rather than merely the post-finding-play. Rats played by the rules, i.e. their behavior was highly distinct between hide and seek trials. Neuronal recordings revealed intense activity in prefrontal cortex that varied according to trial events (initiation, finding, being-found etc.). Hide & seek has found little attention in science, but our findings confirm pet-owner-reports that animals enjoy playing hide & seek. Fast acquisition, strategic behavior, game-adequate vocalization patterns and the game-intrinsic reward value - traits, which emerged without specific conditioning - point to an innate preparedness and to elaborate cognitive and neural capacities for hide & seek in rats.

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Behavioral tracking gets real in the wild

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Manually labeling videos is a commonly used technique to quantify behaviors, but it requires scientists to observe all recordings. This is useful when the repertoire of behaviors of interest is not fully known, but later is tedious and limits sample size. Deeplabcut is a novel cutting edge deep-learning markerless video tracking toolbox that is transforming how neuroscientists quantify behaviors of model organisms like mice and fruit flies. Nevertheless, behavioral ecologists have been slower to implement a general purpose deep-learning video tracking algorithm in the field with non-model organisms. Our research group has addressed this problem by using cost-effective raspberry pi microcomputers in a robotics design that withstands use in the field, followed by an implementation of Deeplabcut, to monitor experimental bee nests in the wild. We tracked over 400 videos of Megalopta bees coming from different nests which vary in their architecture. We also present results of other non-model organisms whose behaviors can be automatically quantified in the wild using this cost-effective robotics and deep learning workflow. These tools helped us process considerably more hours of videos from more nests than would have been possible manually. We will keep writing detailed behavioral descriptions and tallying notebooks, but it is time for us behavioral ecologists to start writing Deeplabcut-python code in jupyter notebooks.

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Body-shaking: a vibratory indicator of reproductives and eggs presence in a subterranean termite

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In insect societies, one of the several tasks carried out by workers is to take care of reproductives and brood, which underline their central role in colony functioning. In this way, several studies highlighted the effect of social composition on worker physiology and behavior (i.e. presence/absence of reproductives, queen-laid eggs but also the presence of non-nestmate individuals). However, while vibratory behaviors are widespread in those societies, very few studies investigate the influence of social composition, and especially social disturbance, on workers' vibratory behavior. Body-shaking is a vibratory behavior widespread among termites and previously described as an alarm behavior in most species. Here we investigate, in the subterranean termite *Reticulitermes flavipes*, if body-shaking displayed by workers is influenced by social disturbances: presence/absence of reproductives and/or eggs. Our results show that the presence of both reproductives and/or eggs enhance workers' body-shaking, suggesting a potential implication of these vibratory cues in social organization. Because colonial fusions occur in this species, we also tested the presence of unrelated reproductives and/or eggs. Interestingly, the vibratory behavior of workers was not modified by the colony of origin of the reproductives and eggs, raising questions about how worker pursue the presence of non-nestmate reproductives/eggs. This study brings new insights into the opened recognition system of R. flavipes and into the overlooked role of vibratory behaviors in social organization of insect societies.

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Can boldness of shoalmate modify personality traits of Deccan Mahseer, a freshwater fish?

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Personality - consistency in the behavioural traits exhibited by an individual across time and context - is known to constrain behavioural flexibility required for adapting with the demands of the contexts. For social animals, living with individuals of similar or contrasting personality traits is unavoidable and limited flexibility in behavioural traits may lead to costly interactions. The present study examined the effect of living with a conspecific similar/divergent in boldness on individual Deccan Mahseer (*Tor khudree*), a freshwater fish, for a period of 15 days. The differences in the nature of social interactions in bold-bold, bold-shy and shy-shy pairs of age-matched individuals and subsequent changes in their propensity to take risk were analysed. The results revealed that the individuals of bold-bold pairs became less bold while members of shy-shy pairs were found to increase their boldness. Interestingly, bold individuals from the bold-shy pairs also became shy, while shy individuals became less timid. Thus, boldness of shoal-mate and resultant social interactions experienced by individuals can modify personality traits like boldness but do not appear to affect other social behaviours such as leadership and sociability in Mahseers. These results could have implications in determining the composition of shoals ideal for cultivation as well as in situ and ex situ conservation of Deccan Mahseers.

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Can chimpanzees, capuchin monkeys and children form abstract rules from minimal input?

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The ontogenetic and evolutionary emergence of the ability to form abstract concepts remains highly debated, both because of mixed results and different interpretations of positive results following long training regimens. Kemp et al. (2007) proposed a computational model of abstract knowledge formation from sparse data, which has not been directly tested in children or in any non-human species. We developed an ecologically valid paradigm in three different versions for testing chimpanzees (*Pan troglodytes*, n=30), capuchin monkeys (*Sapajus spp*., n=22) and 3-5-year-old human children (n=219), and compared it to the model predictions. We presented each species with an evidence phase, in which participants sampled 5-10 items from each of four containers either supporting the abstract rule that each container was filled with a uniform item type or a mix of different types. In a subsequent test phase, participants were presented with two containers simultaneously which only provided low-valued items. As expected for a learner capable of abstract knowledge formation, more children switched earlier in the uniform compared to the mixed condition to the second test box. In the uniform condition, one item is sufficient to predict the content of the first box (all low-valued), whereas in the mixed condition more persistence is expected as there is still a chance for high-valued rewards in the first box. Chimpanzees showed tentative evidence for this pattern in one of three versions but capuchin monkeys' switching behaviour never differed between conditions. This suggests a steep evolutionary increase of abstract concept formation but questions human uniqueness.

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Can personality predict survival in the wild of translocated captive-bred Eastern quolls?

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Conservation translocations are sometimes necessary for restoring or re-establishing populations of threatened species. However, they can be expensive and risky to implement. Personality traits of individual animals may be a factor in determining translocation success. Traits such as bold/shy, reactivity/tameness, exploration/avoidance, aggressiveness and sociability have been linked to an individual's response to predators, interactions with conspecifics and their ability to forage and find shelter. For example, in stable environments, bold, aggressive animals are more likely to have better body condition as they are more able to find the best resources. However, in unfamiliar or unstable environments, such as when translocated, the same animals are more likely to encounter novel threats and not survive. Thus, there is a trade-off in being bold for good health and less bold for survival. An understanding of how personality relates to survival and fitness is particularly relevant for the selection of individuals for translocations. We explore whether personalities of captive-bred Eastern quolls (*Dasyurus viverrinus*) can be quantified via observations prior to translocation, and whether individual personality traits are associated with post-release survival and fitness. In May 2019, 40 quolls will be released into an unfenced, predator managed environment on mainland Australia. Our results aim to reveal whether certain personalities of quolls are better suited to translocation. The selection of individuals with such traits could lead to increased survival of founders, and contribute to establishing a secure wild mainland population of Eastern quolls

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Chimpanzees predict encounter probabilities with food and conspecifics when they revisit fruit trees

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Here, we investigate which social and ecological variables influence the probability that chimpanzee females (N=5) in the Taï National Park, Côte d'Ivoire revisit a previous feeding tree to monitor or eat fruit within an observation period of 275 days. We find a significant interactive effect of the number of individuals that were with the focal female at the tree during the previous feeding visit and the proportion of fruit that was left in the tree after that visit on the approach probability. The probability decreased when more individuals had been present at the previous feeding visit, and thus could have depleted the tree at subsequent visits, but only when the proportion of fruit left in the crown had been low after departure. Crucially, the probability increased when more individuals had been present, but only when the proportion of fruit left in the tree was high. Furthermore, we find a significant interactive effect of the genera of the fruit tree (Ficus or less ephemeral fruit) and the number of days that had passed since the previous feeding visit at that tree. The probability decreased when more days had passed, but only for trees that bore ephemeral fig fruit. We conclude that these findings are best explained by the possibility that chimpanzees keep track of encounter probabilities with fruit and conspecifics, during their daily foraging and travel decisions.

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Communication and the Coordination of Collective Behavior in Wild Baboons

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Recent theoretical and technological developments have advanced our understanding of collective animal behavior, demonstrating how simple, local behavioral interactions can result in complex and adaptive group-level behaviors. The majority of these studies focus on how individuals respond to visual information about the proximity and trajectories of others when moving in simple environments. However, under more complex social and ecological conditions, we might expect inter-individual distance, vegetation, and/or activity to constrain visual information and favor the use of vocalizations for the coordination of behaviors. We are testing this hypothesis in wild chacma baboons (*Papio ursinus*) in Namibia. The baboons range in an 'open' desert environment containing several 'closed' woodland groves along an ephemeral riverbed. This landscape provided a unique opportunity to study collective behaviors under two contrasting levels of environmental complexity that have previously been shown to alter troop synchrony and cohesion. Furthermore, long-term data on this troop enable investigation of how interindividual social relationships affect responses to one another's behavior. We fitted nine adult baboons with bio-loggers that recorded GPS location, accelerometer data, and continuous audio over 30 days. Here we will present preliminary analyses seeking to determine if and how vocalizations shape individual and collective decisions while 'making a move' and 'on the move'. We will discuss our findings in the context of previous research on animal communication, social, and collective behaviors and highlight our upcoming work studying the role of vocal communication in information flow, coordination and collective decision-making.

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Cooperation & Conflict Resolution: my place or yours?

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Group coordination can be difficult to achieve if there is conflict of information between individuals. Although pairs of foraging fish have been shown to resolve directional conflict by turn-taking, it is unclear whether such resolution mechanisms operate among groups. We investigated whether domesticated guppies, *Poecilia reticulata*, resolve directional conflict by turn-taking. Fish were trained to expect food in different zones and tested in different arrangements of sub-shoal size and symmetry. Relative sub-shoal personality differences were also examined to determine whether this difference explained the efficiency of conflict resolution. Our results focus on the role of group size, symmetry and level of 'conviction' in conflict resolution between groups. We discuss the role that individual strength of preference may have, separately from boldness in the resolution of directional conflict.

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Czech and Catalonian treecreepers interspecific interactions

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The most common reason of the competition between two well defined species is niche overlap. The genus Certhia, represented by two species in Europe' *Certhia familiaris* (Eurasian Treecreeper) and *Certhia brachydactyla* (Short-toed Treecreeper), is a good example for studying inter-specific competition. Both species are supposed to differ in their habitat demands, which is true in their extreme preferences, but their habitat preferences may overlap remarkably.

Treecreepers respond quite intensively to a conspecific song. Therefore, we used conspecific playback stimulation (a male song) to map an individual's territory. During the experiment we played 4 song playbacks: a conspecific, a heterospecific (the other treecreeper species), and the Eurasian nuthatch and the European robin (*Erithacus rubecula*) as controls, inside the territory. Each playback was played for 15 minutes, in random order, and was accompanied by a dummy (made of hobby mass for artists) of the particular bird. At least one-hour pause was left between each playback trial. We recorded and measured the distance of the treecreeper from the dummy (loudspeaker), number of attacks, voice response of the treecreeper (number of particular call types), and other displays of stress behaviour.

We compared our results from the Czech Republic with the results from Catalonia and we suggest that interspecific agression of both species is low. Short-toed Treecreeper is as much aggressive towards conspecifics as the Eurasian Treecreeper. The vocalisation use of both species differ. We hypothesize the niche breadth to be the main factor affecting the aggression towards the other species.

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Do capuchin monkeys avoid areas of home range overlap because they are dangerous?

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The Risk Hypothesis suggests that species that engage in lethal intergroup aggression avoid areas of their home range that they share with neighbors due to a fear of fatal confrontations. White-faced capuchin monkeys (*Cebus capucinus*) appear to challenge this hypothesis, as they avoid areas of home-range overlap, even though their intergroup encounters are rarely fatal. However, even non-lethal encounters with neighbors may be costly enough to discourage the use of shared areas. To investigate this possibility, we compared activity budgets, vocalization rates, and foraging behavior of capuchins in central vs. peripheral areas of their home range. Capuchin monkeys spent less time socializing at the edge (vs. in the center) of their home range, but rates of resting, vigilance, and vocalizing did not differ. Fruit trees near range borders tended to contain more ripe fruit, and groups spent more time in these trees with more individuals entering to feed and obtaining more fruits in trees on the edge compared to the center. However, we did not find evidence that capuchins altered their foraging behavior in potentially risky edge areas in a manner consistent with the predictions of optimal foraging theory. Quitting harvest rates were not significantly lower in potentially risky edge areas, and groups depleted food patches to a greater extent at the edge of their range. These results suggest that while peripheral areas of the home range are perceived as risky and contribute to changes in behavior, they also provide important resources that may outweigh the cost of intergroup encounters.

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Do preschoolers and capuchin monkeys infer causes or learn associations?

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The ability to infer unseen causes from evidence is argued to emerge early in development and to be uniquely human (Penn &Povinelli, 2007). We explored whether preschoolers and capuchin monkeys could locate a reward based on a hidden causal event or instead relied on arbitrary associations. Three-five-year-olds (N=68) and capuchin monkeys (N=19) were presented with two cups covered with foil. The experimenter performed two events, first in one order (Test) and then in reverse order (Transfer): 1) She hid a reward behind a barrier, then showed the subject that the foil covering Cup-A was ripped; 2) She poked in downwards motion behind the barrier with a stick, then showed the subject that the foil covering both Cup-A and B was now ripped. If subjects inferred the cause of the ripped foil, they should search in Cup-A regardless of the order of the events; but if they used an arbitrary rule (e.g., choosing the most recently ripped foil), we reasoned that they should make errors when the order of events was reversed in the transfer. Age significantly predicted children's scores: Four- and 5-year-olds performed above chance in both test and transfer. Three-year-olds performed above chance in test but not in transfer. Monkeys performed above chance in both test and transfer, and a follow-up study ruled out reliance on arbitrary cues to solve the task. Our results suggest that by 4 years children used the causally-relevant cue whereas 3-year-olds relied on associations. The role of prior experience on monkeys' performance is discussed.

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Familiarity effects on short-term repeatability and changes in behavioural responses in stickleback fish

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Current and recent social environmental conditions can affect the repeatability of behavioural measures. However, the potential effects of familiarity (e.g. associating with a known or unknown social partner) on the repeatability of behavioural measures remain unexplored. This is surprising given evidence for familiarity effects on behavioural expression in response to novel environments and objects. We studied the behaviour of N=24 pair-housed three-spined stickleback fish (*Gasterosteus aculeatus*) and used high-resolution image-tracking from video to assess: (i) total distance travelled, (ii) individual shelter use, (iii) shared shelter use, and (iv) inter-individual distance, for individuals in two observation trials when paired with either a fish from their own tank (familiar) or from another tank (unfamiliar). Distance travelled was repeatable and decreased across trials, and was not influenced by familiarity. Individual shelter use was not repeatable, increased from trial one to two, and was not influenced by familiarity. Shared shelter use was repeatable for unfamiliar but not familiar dyads (which could be a result of the novelty of both the social partner and the physical environment), and increased from trial one to two. Inter-individual distance was not repeatable and increased from trial one to two, and was not influenced by familiarity. Overall, this study indicates familiarity does not affect short-term repeatability and changes in behavioural measures commonly used in animal personality research, and we discuss the implications of our findings for testing fish in behavioural experiments.

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Genetics of behavioural isolation in Heliconius butterflies

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The evolution of new species relies on the accumulation of genetic differences that result in reproductive barriers. These barriers frequently act before mating, and many closely related taxa remain separate because they effectively 'choose' not to mate in the first place. Although the significance of behavioural barriers has been recognized at least since the Modern Synthesis, we still know very little about the genetic changes that underlie behavioural divergence in natural populations, or how they are mediated during development. The warning patterns of *Heliconius cydno* and *H. melpomene* are under disruptive selection for mimicry, and are also used during mate recognition. We report a genome-wide QTL analysis which reveals that divergent mate preference between these species has a surprisingly simple genetic basis. Three QTLs explain 60% of the difference in preference behaviour observed between the parental species. One of these QTLs is physically linked to the major wing patterning gene optix, which causes a switch in forewing colour from white to red. By integrating these results with gene expression and population genomic analyses, we identify a candidate gene responsible for shifts in visual mate preference behaviours, specifically a regucalcin, previously implicated in synaptic transmission or plasticity. Genetic associations between loci for ecological and assortative mating traits are predicted to facilitate speciation in the face of gene flow. Our data also suggest behavioural alleles may be acquired through introgression, allowing reassembly of existing genetic variation, further facilitating the rapid evolution of novel behavioural phenotypes and speciation.

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Harsh winters influence the success of colony founding in a socially polymorphic ant

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The structure of animal societies often co-varies with altitudinal gradients, suggesting that alternative social forms are adapted to different ecological conditions. The Alpine silver ant has two types of colonies coexisting within populations: some colonies have a single breeding queen (monogynous) and others have several breeding queens (polygynous). Colony social organisation is genetically determined. Across independent elevation gradients, monogynous colonies are more frequent at high elevation, whereas polygynous colonies are more common at low elevation. Here, we experimentally investigated whether social origin and environmental conditions jointly influence the success of newly mated queens during independent colony founding. We hypothesized that queens from monogynous colonies would be more successful at independent colony founding in harsh environments, as they are larger and have more body fat reserves. We placed queens to hibernate in either a 'harsh' or a 'mild' winter and recorded their fecundity and survival for one year. Queens originating from monogynous colonies had higher survival than queens from polygynous colonies after a harsh winter, while both types of queens had similar survival after a mild winter. Queens of monogynous origin were more fecund than queens of polygynous origin, independently of the winter type. Our results suggest that harsh conditions limit the success of polygynous queens during independent colony founding, which may help explain why polygynous colonies are less common in higher-elevation populations.

How do chimpanzees (*Pan troglodytes*) overcome conflicts of interest to coordinate their actions?

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Coordinating decisions and actions is a vital aspect of living in a group for social species such as chimpanzees (*Pan troglodytes*). In many cases successful coordination requires some individuals to pay a cost, e.g. although individuals have differing preferences for the direction of travel, it is necessary to agree on one if they are to travel as a group. The aim of the current study is to understand how individuals resolve these conflicts of interest while avoiding coordination failure and whether they able to use knowledge about other's behaviour to gain strategic advantage. We presented captive chimpanzees with a task based on the Volunteer's Dilemma: highly preferred food was placed out of reach inside boxes (one for each individual), the food could be accessed for a short period of time if one individual paid the cost of volunteering by moving to another location to activate the release mechanism. This individual thus had less time to access the food reward. If no-one volunteered the food remained inaccessible. When there was the possibility of a partner paying this cost, they waited for others to volunteer even when this occasionally resulted in coordination failure (no reward) although all of these chimpanzees were willing and able to use the release mechanism for themselves when tested alone. We also found that chimpanzees adjusted their actions to changes in the costs and benefits of volunteering.

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Human attention affects facial expression in dogs

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Most mammalian species produce facial expressions. Historically, animal facial expressions have been considered inflexible and involuntary displays of emotional states rather than active attempts to communicate with others. In the current study, we aimed to test whether domestic dog facial expressions are subject to audience effects and/ or changes in response to an arousing stimulus (e.g. food) alone. We presented dogs with an experimental situation in which a human demonstrator was either attending to them or turned away, and varied whether she presented food or not. Dogs produced significantly more facial movements when the human was attentive than when she was not. The food, however, as a non-social but arousing stimulus, did not affect the dogs' behaviour. The current study is therefore evidence that dogs are sensitive to the human's attentional state when producing facial expressions, suggesting that facial expressions are not just inflexible and involuntary displays of emotional states, but rather potentially active attempts to communicate with others.

Increased terrestriality in a Neotropical primate living on islands with reduced predation risk

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The absence of terrestriality among New World monkeys is notable and raises questions about the ecological pressures that constrain the expansion of platyrrhines into terrestrial niches. We took advantage of a natural experiment to test the hypothesis that terrestrial predators constrain primates' exploitation of terrestrial niches.

We used camera-traps to compare patterns of terrestrial behavior in white-faced capuchin monkeys (*Cebus capucinus imitator*) living on two islands off of the Pacific coast of Panama that lack mammalian predators and at three sites in central Panama with more intact predator communities. We compared detection rates, party size and duration of terrestrial events, and estimated the timing of terrestrial activity.

We found that white-faced capuchin monkeys living on islands exploit terrestrial niches more extensively than their counterparts living in habitats with a more intact predator community. Camera trapping revealed differences in the frequency and timing of terrestrial activity in these capuchin populations, as well as differences in the number of individuals observed on the ground. The range of party size observed was larger and individuals engaged in a wider range of terrestrial behaviors on the islands.

These findings support the hypothesis that predators constrain primates' exploitation of terrestrial niches. They are also consistent with the hypothesis that arboreal locomotion imposes costs that primates will avoid when predation risk is low. Our findings demonstrate that under the right ecological conditions, capuchins can readily expand into terrestrial niches, and suggest that reduced predation risk may be key to the adoption of a more terrestrial lifestyle.

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Individual behavioral variation as a tool for conservation? A New Zealand case study

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There is a growing recognition among behavioral ecologists that individuals within species vary in their behavior. Meanwhile, conservation biologists have long considered variation a safeguard against environmental change but have largely focused on genetic differences. As threatened populations continue to shrink, each individual has an increasing impact on its species' survival, and the need for efficient interventions grows more urgent. Understanding the extent to which behavior varies could help us tailor management strategies to the unique needs of these remaining individuals. The hihi (*Notiomystis cincta*), a threatened New Zealand passerine, is one such species for which behavioral variation could have meaningful conservation implications. Following near-extinction around 1890, hihi have been reintroduced to several island and mainland sites, but habitat suitability (including food availability) has proved a major barrier to establishing self-sustaining populations. At the species level, hihi eat a generalist diet, but they meet many criteria predicted to drive dietary specialization: their physiological needs change with age, they exhibit intra- and interspecific dominance hierarchies, and they inhabit heterogeneous landscapes. Here, we assess dietary variation in the Tiritiri Matangi Island population, showing that this generalist species may actually be composed of specialized individuals. We also find that dietary differences link to social interactions among and within species, suggesting possible dominance effects. Finally, as this population is a frequent source for translocations, we discuss whether dietary variation could help us improve reintroduction efforts by identifying individuals that will be more likely to survive and thrive in a new environment.

Individual consistency and social flexibility modulates the waggle dance of honey bee foragers

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Individuals in social groups need to integrate information from social cues and signals into their behavioural responses. At the same time, individuals may also show consistent differences in their behavioural responses. The interplay between social interactions and consistent inter-individual differences within such groups remains largely unexplored.

In eusocial insect groups, social cues and signals play a vital role in ensuring efficient division of labour amongst the workers. Foraging, for example, involves interactions between multiple workers in the hive. The waggle dance behaviour of foragers acts as the main regulatory mechanism of foraging and incorporates cues from the environmental and social context.

In this talk, I will present results from our work on the social modulation of individual differences in the waggle dance activity. Observations of individual foragers over consecutive days revealed consistent inter-individual differences in the probability and intensity of the dance activity. Manipulation of the social environment by removing some foragers led to more active foragers changing their dance activity. This change in activity was greater in the probability than the intensity of dancing. Lab assays and agent-based model simulations provided further evidence that intensity of dancing is a more intrinsic behavioural parameter, whereas the probability of dancing is more flexible with respect to social cues.

Our work reveals a fine scale division of labour within honey bee forager groups. It also reinforces the importance of the social context in task performance in eusocial insects and highlights the role of social interactions in maintaining consistent individual behavioural patterns.

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Integrating synchrony, skin and sexual contact to assess pathogen transmission risk in dolphins

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Pathogen and parasite transmission is fundamentally driven by a population's contact network structure, and is further influenced by its demographic composition. Importantly, populations are most often concurrently exposed to a suite of pathogens, which is rarely investigated. Using detailed long-term data of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), we quantify the demography-dependent exposure risk associated with three different transmission routes (sexual contact, skin contact, and droplet contact of respiratory vapour above the water surface), quantify co-exposure risks and relate them to individual sociability. Our results suggest demography-driven disease implications in bottlenose dolphins, with males at greater risk than females. We hypothesize that male alliance-formation and the divergent reproductive strategies in males and females drive the demography dependent exposure risk to pathogens. Our study provides evidence for the risk of co-exposure to pathogens transmitted along different transmission routes and that they relate to individual sociability. Hence, our results highlight the importance of a multi- behavioural approach for a more complete understanding of the overall pathogen transmission risk in animal populations, as well as the cumulative costs of sociality during animal life histories.

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Innovation in wild Barbary macaques' inter-individual differences in a novel foraging task.

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The ability to innovate and the social transmission of innovations have played a central role in human evolution. However, innovation may also be crucial for many other species, by allowing them to successfully cope with socio-ecological challenges, for instance, by exploiting novel food resources. In this study, we conducted behavioural observations on a group of wild Barbary macaques (*Macaca sylvanus*) on Gibraltar and presented them with a novel foraging device, which they had to manipulate to obtain food. The device was completely transparent, with the exception of one functional part (i.e. lid, tab or stick). Depending on the condition, food could be accessed by rotating a lid, pulling a tab, or pushing the food out of the box with a stick. More devices were simultaneously present, to also allow access to lower-ranking individuals. Across 400 trials, 14 different individuals participated in this task. We monitored whether individuals preferentially manipulated functional versus non-functional parts of the box, and whether they generalized across conditions by preferentially accessing functional parts. We further assessed inter-individual differences in the ability to solve the task, and which factors best predict these differences. In particular, we analyzed the effect played by sex, age, rank, inhibition, neophobia, persistence, exploratory skills, social centrality and strength, and presence of others on the ability to innovate. We discuss our results in line with existing and novel evolutionary hypotheses on the emergence of innovation, and hint to possible future directions for research.

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Insight problem-solving in meerkats (*Suricata suricatta*)

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Insight behaviors are adaptive and innovative solutions to problems in the environment. Such responses arise without explicit training, so are considered evidence of higher cognitive abilities, such as reasoning. For example, after the perceptual experience with the landscape the animal infers the best way to approach the goal, which can be shelter, food or a mate. No test of insight behaviors in meerkats has been reported yet. In our test the meerkats saw the food from the ground, but they only could get it after climbing a ramp and going through a bridge Once at the top of the bridge, if they pulled, in vertical direction, a piece of white net mesh fabric, they could reach mealworms. Fifteen meerkats of the Barcelona Zoo were tested on this task, the objective was to measure their ability to solve it by insight, namely in a spontaneous, continuous and direct way. In an individual pretest, without any prior manipulation, neither meerkat solved the task. Then, after 72 hours-habituation to the apparatus without any food on it, one subject solved the task in an individual test (now with worms), but none of the other did in individual, or in subsequent group tests. Finally, after individual and group training to climb the ramp and to walk through the bridge without the net present, one meerkat solved spontaneously in an individual test, two solved the test spontaneously in the group test, and another one solved it in the group test after several attempts to pull the net without eating the worms. These results suggest that meerkats solved new problems spontaneously. However, exploration of the elements of the problem and knowledge of prerequisite behaviors may be necessary for the appearance of insight in meerkats.

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Investigating how baboon behaviour and ecology contributes to Guinea worm transmission in Ethiopia

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While the use of animal models to examine human disease and the study of animal behaviour in response to disease are widespread, the concept of understanding animal behaviour to inform control of human disease remains largely unexplored. An increasing number of 'human' neglected tropical diseases are being detected in non-human primates, indicating that insights into how wild animals contract and transmit such diseases may be crucial to disease management and eradication. We investigate the behaviour and ecology of a social species, the olive baboon (*Papio anubis*), in Gambella, Ethiopia to test the hypothesis that Guinea worm disease (dracunculiasis) may persist in the region due to human-animal transmission. We combine observations of social behaviour from six focal troops with ranging data over 12 months from manual tracking and GPS collars, and dietary data from stable isotope analyses of whiskers to elucidate how baboon behaviour puts them at risk of Guinea worm infection. By linking these behavioural, dietary and ranging information to data on infection history obtained from serology tests of blood samples from individuals, we assess whether certain individuals are more likely to contract and transmit dracunculiasis due to their social position/rank and associated foraging behaviours and/or access to resources. Information on baboon interactions (drinking, eating fish/frogs) with water bodies also used by humans will be particularly informative for control efforts. Our work provides important evidence to inform the new frontier of Guinea worm eradication, plus broader insights into the role non-human social species may play in transmission of human disease.

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Learning and personality: Better to be bold?

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There is a body of evidence to suggest that personality, the study of consistent differences in individual behaviour across time and context, influences learning outcomes in both humans and non-humans. This has important implications on the selection criteria for working animals who are required to perform certain tasks efficiently and effectively. To investigate this relationship, we performed a boldness assay across two contexts (novel object and open field) to determine the individual boldness scores of 30 animals. Scores were then compared to performance in an odour discrimination task. Preliminary results suggest that the less bold individuals learnt the task faster. Previous studies have posited that this relationship may be a result of less bold animals being at an advantage when changes in the environment are relevant to the task. This relationship between personality type and performance should be considered during the selection of working dogs.

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Chimpanzee perception of visual communicative signals

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Chimpanzees, in the wild and captivity, are known to distinguish between their various vocal signals. This capacity has been successfully demonstrated by call playback experiments. Although chimpanzees frequently communicate with both facial expressions and gestures, knowledge on how they perceive these visual communicative signals is sparse. To address this issue, we developed a two-pronged approach with eyetracking and match-to-sample touchscreen experiments. In the eyetracking experiments, we used images of chimpanzee facial expressions versus neutral faces and gesturing chimpanzees versus their neutral body states, to test if they look differently at visual signals compared to neutral states. In the match-to-sample experiments we tested if chimpanzees match images of visual signals to other exemplars of visual signals rather than non-matching foils, enabling us to probe how chimpanzees categorise visual signals. These studies are ongoing with the 15 chimpanzees at the Budongo Research Unit of the Edinburgh Zoo, UK. This is the first systematic experimental study, using two different methodologies, to understand chimpanzees' perception of conspecific visual signals.

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Mechanisms and consequences of collective migration in juvenile white storks

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Many migrating animals move together, sometimes in groups of thousands of individuals. Thus, to understand the mechanisms and consequences of these seasonal movements fully, we must explore animal trajectories within their social context. Investigating groups of wild migratory birds empirically is challenging, but with state-of-the-art tracking technology that record the simultaneous movements of multiple individuals at extremely fine spatial and temporal scale it is now possible to connect an individual's behaviour and physiology to its group and environment. Here we describe how collectively migrating white storks use social cues for locating and exploiting thermal updrafts by relying on leading and following behaviour. In addition, we show that collective stork migration involves group cohesion among individuals with variable movement capacities and costs, indicating that group composition is essential for successfully reducing movement costs. By unravelling the use of different collective migration mechanisms in a natural environment, we highlight the importance of combining experimental behavioural research with ecological in situ observations and suggest that integrating intraspecific interactions into migration research will enable a better, more mechanistic understanding of broad-scale ecological processes.

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Mixed support for state maintaining risky personality traits in yellow-bellied marmots

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In a variety of taxa, individuals behave in consistently different ways. However, there are relatively few studies that empirically test the potential mechanisms underlying the causes and maintenance of these personality differences. Several hypotheses for the causes and maintenance of risky personality traits have been suggested but all have received mixed support. Two major hypotheses, the pace-of-life and state-dependent safety hypotheses, propose that differences in internal state cause and maintain personality traits. Formally, the pace-of-life hypothesis states that differences life-history strategy including productivity (growth) and residual reproductive value (age) create initial differences in individual behaviour and then positive feedback maintains these differences, while the state-dependent safety hypothesis suggest that body condition (mass) is responsible for causing and maintaining behavioural differences. We tested and evaluated these two hypotheses explaining causes and maintenance of variation in risk related personality traits- defensive aggression, activity and exploration- in yellow-bellied marmots (*Marmota flaviventer*). We found little support overall for these hypotheses in explaining maintenance in activity or exploration. However, for defensive aggression, we found positive feedback for both mass and age.

Cat Fight Amongst the Sexes: promiscuous lionesses win the gender war of fitness

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To maximize individual fitness, males and females of the same species often engage into strategies that are at loggerheads. Sexually selected infanticide is a male strategy that is costly for females, as killing of dependent young by males cause considerable losses to maternal investments. African lions are social, with a group comprising of females, their cubs and a coalition of adult males. Coalition males maintain territorial exclusivity on a group of females and sire all cubs born to a pride during their tenures. Infanticide is prevalent among lions where incoming males kill cubs during a 'takeover', after ousting the resident males. Asiatic lions, living as a single relic population in India exhibit a contrasting social structure with males and females staying separately. In here male ranges encompass multiple female groups and vice-versa. We investigate consequences of such social organisation on the mating strategy of Asiatic lions. Long-term observations on 134 mating events between 21 males and 49 females revealed that lionesses are promiscuous, females readily mating with multiple rival coalitions. However, promiscuity was primarily shown by experienced lionesses who have had litters before. Selective female promiscuity has considerably buffered cub infanticide by confusing paternity amongst males, reduced sexual harassments, and also might have invigorated an inbred population by increasing genetic diversity of litters. This novel mating strategy for lions might have evolved owing to spatial segregation between the genders caused by smaller modal prey in the Asiatic system. Our results thus highlight resource mediated behavioural plasticity amongst territorial species inhabiting diverse eco-regions.

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New Technological Approaches to Study Sensory Aspects of Foraging Behavior in Wild Bats

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New technologies allow us to record the location (GPS), movement (accelerometer) and acoustic behavior (microphone) of bats while they are behaving freely in the wild. Here, we present two case studies where we use these technological advances to assess different aspects of bat foraging.

We compared GPS tracks and echolocation of five different bat species. Linking the movement with sound recordings, we evaluated not only the foraging behavior of individual bats, but also recorded the presence of close-by conspecifics. We found that species that search for ephemeral prey, which is hard to predict in space and time, fly together in a group. Listening to their conspecifics' echolocation calls increases their detection range of prey and therefore the likelihood of finding patchily distributed food resources.

For one of those species - the greater mouse-eared bat, *Myotis myotis* - we analyzed the foraging behavior in more detail. GPS tracks informed us on the nightly, stereotypical foraging routes and large-scale strategies that these bats employ. The analysis of body movement and echolocation behavior gave unprecedented fine-scaled insights into the actual foraging behavior of individual captures. Our acoustic recordings described the dynamics of this species' echolocation when listening for prey-generated sounds and hunting airborne prey. Finally, we could not only distinguish between different foraging modes (aerial vs. ground capture), but also evaluate the attack success rate and possible prey type. This kind of data can inform us on important basics of foraging and thereby open up possibilities to estimate optimal foraging strategies.

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Can deep neural network score bird song similarity?

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Deep neural network is a machine learning network that can extract higher level features (similarity, identification, etc.) from lower level input (i.e. spectrogram). Due to its strong computational power, it can process a magnitude of multi-dimensional interactions. Therefore, it is suitable to analyze bird songs where the temporal, spectral and sequential features are densely intertwined. Song similarity is an important index to study songbird cognition. We have trained a Siamese network [SongSim], a specific neural network that can learn to calculate similarity, to score similarity between any two given zebra finch songs and evaluated the results by checking how the network scores songs from the same bird.

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Shared behavioral mechanisms underlie *C. elegans* aggregation and swarming

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In complex biological systems, simple individual-level behavioral rules can give rise to emergent group-level behavior. While collective behavior has been well studied in cells and larger organisms, the mesoscopic scale is less understood, as it is unclear which sensory inputs and physical processes matter a priori. Here, we investigate collective feeding in the roundworm C. elegans at this intermediate scale, using quantitative phenotyping and agent-based modeling to identify behavioral rules underlying both aggregation and swarming—a dynamic phenotype only observed at longer timescales. Using fluorescence multi-worm tracking, we quantify aggregation in terms of individual dynamics and population-level statistics. Then we use agent-based simulations and approximate Bayesian inference to identify three key behavioral rules for aggregation: cluster-edge reversals, a density-dependent switch between crawling speeds, and taxis towards neighboring worms. Our simulations suggest that swarming is simply driven by local food depletion but otherwise employs the same behavioral mechanisms as the initial aggregation. We further expand our work by examining swarming at very high densities, and using a bioluminescence bacterial system to visualize and quantify feeding.

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Old Age Primates (OAPs): Locomotion and musculoskeletal disease in ageing populations of chimpanzees

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Continuous improvements in zoo animal welfare have led to extended lifespans compared to wild conspecifics, particularly for the great apes. With ageing in humans, we commonly see slower more unsteady movement, increased risk and fear of falling, and musculoskeletal disease, namely osteoarthritis. Given the challenging environment that wild apes must move around in, if present, these age-related impacts ought to be more salient. Osteoarthritis in particular is thought to be a disease of sedentary lifestyles, where inactive joints are poorly maintained, and cartilage breaks down. Evidence comparing wild and zoo chimp activity is limited, but suggests captive chimps are more sedentary, ergo prone to osteoarthritis. This research seeks to quantify how chimpanzee positional behaviour and locomotor ecology (movement and posture in a given environmental context) are impacted by ageing, and whether a potentially more sedentary lifestyle has adverse risks to joint and bone health.

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Oxytocin increases after affiliative interactions in male Barbary macaques

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Oxytocin (OT) is a neuropeptide hormone implicated in the formation of social bonds. It is often released in response to positive social interactions, though this can be context and/or partner specific. Here, we investigate the effect of affiliation - grooming and triadic male-infant-male interactions - in a non-reproductive context with bonded and non-bonded partners on urinary OT levels in semi-free ranging male Barbary macaques. We collected data on social behavior during full-day focal protocols on 13 adult males and measured endogenous OT levels from 185 urine samples collected after affiliation and non-social control periods during one non-mating season. We used a window of 15-60 min to excretion of OT in urine after a target behavior. OT levels tended to be higher following affiliation with any partner and with bond partners but not after affiliation with non-bond partners compared to non-social controls. Testing grooming and triadic interactions separately, we found OT levels were significantly higher after grooming with any partner and tended to be higher after grooming with bond partners. By contrast, OT levels after triadic interactions with any partner or with bond partners were not significantly different from controls. We could not test for independent effects of grooming or triadic interactions with non-bond partners due to small sample sizes. Our results are in line with previous studies showing that OT levels are increased after grooming, although it is still unclear whether OT release is partner-specific. The lack of an effect of triadic interactions on OT levels is puzzling and will be discussed.

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Personality influences breeding response to corticosterone in a long-lived bird

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Carry-over effects occur when energetically demanding events in the past shape future reproductive attempts. Glucocorticoid hormones are important mediators of carry-over effects, with recent work in birds showing that corticosterone in feathers (fCORT) can predict future breeding decisions and success. However, individuals vary widely in how they respond to fCORT, potentially due to the existence of different life-history strategies: the trade-off between investing in current or future reproduction manifests in different life-history strategies at the individual level, which often correlate with personality. Fast-paced, bold animals preferentially allocate resources towards current reproduction, while slow-paced, shy animals prioritise survival. Accordingly, carry-over effects are predicted to vary with personality, with shy individuals responding to stress by reducing allocation to current reproduction more readily than bold individuals. Here, we examine the influence of personality on carry-over effects in a long-lived seabird, the black-legged kittiwake (*Rissa tridactyla*). To assess the strength of carry-over effects, we measured concentrations of the stress hormone corticosterone (CORT) in feathers grown at the end of the previous breeding season. We then examined breeding responses to these CORT levels, specifically focussing on phenology, clutch size, and success, and tested the influence of personality on carry-over effects. We demonstrate carry-over effects of CORT on breeding phenology, and we show that the strength of this effect varies with personality: shy individuals adjusted the timing of breeding in response to stress more strongly than bold individuals. Our results emphasise the importance of considering individual differences when interpreting the effects of environmental stress on fitness.

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Personality niches across relationship components of the bottlenose dolphin (*Tursiops truncatus*) social network

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Social structures are critical to the success of gregarious species. Rapid advances are being made in understanding how small scale processes, such as consistent individual variation, impact social structures. Personality similarity predicts dyadic bonds, which are the basis of social structures. Thus, personality should be related to an individual's location in the social network. Boldness predicts network centrality, but other personality factors have yet to be investigated. Additionally, multiple species display evidence of social relationship components, and new analysis methods incorporate information from these components into network models simultaneously. Here we analyzed the social network metrics of individuals with different personalities to determine their role in their social group. A population of bottlenose dolphins (*Tursiops truncatus*) in a naturalistic environment under human care served as an easily observable proxy for wild populations. Personality was assessed using a Five-Factor Model questionnaire. Association was defined as within one body length of at least one other group member. Bond components (termed affiliative support, sociosexual, and conflict play) were determined by grouping interactions recorded during underwater opportunistic focal-follow via exploratory factor analysis. The role of personality types in the social group was determined using a multilayer network, with association and relationship components as layers. Openness and Extraversion were correlated with high centrality within and between layers. Neuroticism had a weak inverse correlation with centrality, but not across all layers. This furthers our understanding of the role personality types play in their social network, and demonstrates variation in these roles between social components.

Proximate mechanisms underlying alternate behavioral strategies in the facultative cleaning goby *Elacatinus prochilos*

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Cleaner fish are conspicuous members of coral reef communities that remove ectoparasites and dead tissue from larger fishes, referred to as 'clients'. In the Caribbean, the cleaning goby *Elacatinus prochilos* is a facultative cleaner that exhibits two alternative behavioral types, which are linked to habitat use. Individuals living in corals or other substrates (coral-dwellers) depend mostly on cooperative cleaning interactions with client reef fishes for feeding. Alternatively, individuals living in basket sponges (sponge-dwellers) feed mostly on micro-organisms living inside the sponges' tissue and only rarely engage in cleaning interactions. Previous studies have shown that obligatory coral-dwelling species prioritize predatory clients and secrete levels of cortisol after facing them. Here, we aimed to investigate how the two behavioral types in the facultative species behave towards predatory and non-predatory clients in controlled laboratory conditions and whether their whole body cortisol levels correspond to their cleaning behaviors. We found that wild coral-dwelling gobies have significantly higher whole-body cortisol levels than sponge-dwellers. Behavioral observations revealed that although the two behavioral types did not differ in their latency to interact with either predatory or non-predatory clients, sponge-dwellers interacted significantly less with clients than coral-dwellers in the lab. These results show that the *E. prochilos* with higher levels of cortisol also exhibit higher frequencies of cleaner interactions. However, these facultative coral-dwellers did not give priority of service to predatory clients as do obligatory coral-dwellers. Further studies should aim to investigate which factors cause the increase of cortisol in coral-dweller types and how it affects individual fitness.

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Quantifying social complexity in Lamprologine cichlid species

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The complexity of the social environment has been proposed to be a key driver of the cognitive evolution of animals. Despite recent progress in conceptualizing social complexity, identifying a unifying index that allows comparisons across taxa still remains a major challenge. Here we propose a simulation that employs social network analytical metrics and takes on an information theoretical point of view to provide a quantitative assessment of social complexity. By constructing dynamic social networks of varying size, edge density, interaction density, relationship stability and breadth of behavioral repertoire we assess the relative contribution of these parameters in driving the systemic unpredictability as perceived from the perspective of an individual embedded within the network. In order to illustrate a case example of how our model-based approach could be applied to real-world data, we investigate the social behavior of shell-dwelling Lamprologine cichlid species which exhibit striking ecological similarities, but differ substantially in their social organization. After reconstructing species-stereotypic social networks, we compare the model predictions to estimate the level of complexity that each species is facing in natural contexts. In so doing, we gain insight into the social sources of selection that underlie the evolution of neuroanatomical and socio-cognitive features in a quantitative, comparative framework employing both empirical and theoretical approaches.

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Responses of female bank voles, *Myodes glareolus* to male chemosignals

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Female mammals often need to locate and assess potential mates to ensure they reproduce with high quality males. Scents may play an important role in facilitating female location and assessment of males, particularly in solitary species where individuals interact infrequently. Further, female mammals often discriminate between male odours based on social status, territory ownership, health, genetic quality and age. Mammalian odours are highly complex, often containing hundreds of volatile and non-volatile compounds. Male bank voles invest heavily in urinary scent marking and produce a urinary protein, glareosin, which is upregulated during the breeding season, so may function to attract females. Proteins are expensive to produce so urinary protein production may be an honest signal of male quality. Alternatively, such proteins may function to bind smaller volatile ligands slowing their release. Recently, we have identified a volatile ligand present in male urine which may also play a role in sexual attraction in this species. Here, we investigate the response of female bank voles to male chemosignals by combining behavioural tests with molecular analysis of male scents. Combining molecular techniques with behavioural testing has allowed us to determine the functional importance of different components of male scent and has given us greater insight into the mechanism underpinning this important female behaviour.

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Reversal learning and cognitive flexibility under realistic conditions of multiple different choices

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The extensive use of reversal learning as a measure of cognitive flexibility is typically based on training an animal to discriminate between rewarding and non-rewarding stimuli, and then reversing their roles. In natural conditions, however, animals are likely to face more than one set of relevant stimuli, which may substantially impact the dynamics of reversal processes and their implications for foraging success. Here, we address this possibility by studying reversal learning in captive socially foraging house sparrows. Sparrows were initially trained to prefer one of two colors or one of two shapes (creating color or shape specialists) and then allowed to forage on foraging grids containing both colors and shapes. We noted that during training, color specialists learned faster to discriminate between the rewarding and non-rewarding stimuli, compared to shape specialists. After the roles of the rewarding and non-rewarding colors and shapes were reversed, shape specialists (including those exhibiting exclusive use of the rewarding shape) quickly reversed their preference to the new rewarding shape. Color specialists, on the other hand, failed to reverse to the new rewarding color but gradually shifted to the new rewarding shape. These results suggest that: a) marked differences in reversal behavior may be explained by the type of learned stimuli rather than by individual differences in cognitive flexibility; b) under realistic conditions of more than two foraging options, strong initial preferences that are difficult to reverse, may drive a flexible shift to a new rewarding stimulus rather than to the previously non-rewarding option.

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Risk of dynamic social colours in a tropical agamid lizard

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Across different taxa, there is incredible variation in colour signals of animals. Such variation can result due to differences in sexual selection and predation pressure, such that the benefits of conspicuous colours for social interactions are constrained by the costs associated with high predation risk. However, empirical evidence for the predation cost of conspicuous colour signals, especially those differentially expressed during different social contexts, is limited. In this study, we quantified predation risk on the Indian rock agama (*Psammophilus dorsalis*), a species where males express distinct physiological colours during different social contexts, while females remain cryptic. We first estimated the conspicuousness of the different colours expressed by the lizards to the visual systems of their typical predators. We then deployed wax models of lizards that were painted to resemble males in courtship colour, males in aggression colour, cryptic females, and cryptic males, across multiple sites. We find that not only was the courtship colour most conspicuous, the models bearing this colour were attacked the most by avian (raptors) and terrestrial (dog) predators. Our results suggest that colour change may have evolved in P. dorsalis to balance the benefits of sexual signalling with the risk of predation.

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Scrounging enhances the diffusion of a novel foraging behaviour in domestic chicks, *Gallus gallus domesticus*.

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Animals foraging within a group can transfer profitable information, through social learning, about discovered food patches, novel food items and foraging techniques. However, during social foraging, instead of performing the novel foraging behaviour themselves, naïve individuals will commonly adopt a scrounging tactic and acquire food that has been obtained by others, termed producers. It is commonly assumed that social learning of new behaviours is inhibited by the opportunity to scrounge food; a premise supported by multiple laboratory experiments showing learning to occur only when scrounging behaviour is prevented. We investigated the effect of scrounging opportunities on the spread of a socially-learned foraging behaviour through a group of domestic chicks, *Gallus gallus domesticus* using a natural information diffusion approach. We manipulated scrounging opportunity by altering the quantity of food reward while maintaining group sizes and learning opportunities. We found that the opportunity to scrounge food from others was essential for the novel foraging behaviour to spread throughout the group. Furthermore the speed of behaviour spread appears to be directly proportional to the level of scrounging opportunity present. Therefore contrary to previous assertions, scrounging may facilitate the transmission of socially learnt behaviours. The opportunity to scrounge, often determined by the divisibility of the resource in question can determine the learning and spread of new behaviours within a group of animals.

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Sensitive periods for personality development in a medium-sized rodent

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The study of consistent individual differences in behaviour, termed animal personality, has flourished over the last two decades because it has been recognised as a major contributor to differences in survival and fitness among individuals. How personality develops during life and how the early environment influences adult personality on the other hand has only started to be investigated. Sensitive periods - developmental stages in which environmental cues shape the phenotype to a larger extent than in other stages - may shape personality characteristics and help individuals to adjust optimally to the environment.

To identify a sensitive period for the adjustment of risk-taking, stress-coping and social personality traits, we experimentally manipulated stress-hormone levels during three life stages (juvenile, adolescent, adulthood) in wild cavies (*Cavia aperea*). We tested immediate and long-lasting effects of the manipulations on expression of personality traits as well as their temporal consistency. While we found an immediate effect of the experimental manipulation in juvenile and adolescent animals, the manipulation only induced permanent changes in personality types in adolescent but not in juvenile animals. Both, juvenile and adolescent cavies with experimentally increased stress-hormone concentrations developed a passive stress-coping strategy but this effect diminished during adolescence in animals treated as juveniles. Neither risk-taking nor social traits were affected by the treatment and adult individuals did not show any alteration of personality characteristics. These results indicate that especially the stage of adolescence is an important sensitive period during which the animals adjust their personality long-lasting to the prevailing environmental conditions.

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Social learning strategies and advice giving regulate human collective intelligence

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Why groups of individuals sometimes exhibit collective "wisdom" and other times maladaptive "herding" is an enduring conundrum. Here I present that this apparent conflict is regulated by the social learning strategies deployed. I examined the patterns of human social learning through an interactive online experiment with 699 participants, varying both task uncertainty and group size, then used hierarchical Bayesian model-fiting to identify the individual learning strategies exhibited by participants. Challenging tasks elicit greater conformity amongst individuals, with rates of copying increasing with group size, leading to high probabilities of inflexible herding amongst large groups confronted with uncertainty. Conversely, the reduced social learning of small groups, and the greater probability that social information would be accurate for less-challenging tasks, generated "wisdom of the crowd" effects in other circumstances. Additionally, through a laboratory experiment with 194 subjects where participants could share 5-star ratings about options quality in addition to inadvertent choice-frequency information, I found that, even though the 5-star rating was a useful cue to predicting objective option-qualities, participants performed worse when both types of social information were combined than when only the frequency information was available, resembling the "less-is-more" effect in the judgment and decision making literature.

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Social network dynamics and home-range overlap among horses in extremely seasonal habitats

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Feral Retuerta horses in Doñana Biological Reserve experience dry summer and fall and in winter marshes may flood large areas of the reserve. These dramatic environmental changes affect availability of forage and water and may thus affect the social structure of the horses. We tested the hypotheses that during the dry season 1. Groups show a greater overlap in home-range, due to scarcity of patches of food and water and 2. Network modularity will be lower, due to increased opportunities for mixture of groups when using the few available patches. We documented horses' group affiliation between July 2014-Feb 2015, and divided these months to a dry and a wet season, based on monthly rainfall and NDVI. We analysed the weighted social networks separately for the two seasons and compared them.

Ten harems were detected in both seasons and a few of them remained mostly unchanged. However, the composition of some of the groups was very different: a few groups split or merged, and a few horses died towards the end of summer. Group home-ranges overlapped more during the dry season, however, network modularity was higher in the dry season, i.e., groups were less inclined to mix. We hypothesize that in addition to the distribution of resources, the presence of flies may have affected the movement and the cohesion between individuals in summer.

Song syllable sharing in male and female New Zealand bellbirds

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An understanding of spatial patterns of song sharing and sex differences in song diversity can reveal insights into the function and evolution of bird song. In systems where males and females are territorial, sedentary, and sing complex song, there is an opportunity to explore how sex differences in song sharing may influence the formation and maintenance of song dialects. In this study, we examine male and female song syllable diversity in an island population of the New Zealand bellbird (*Anthornis melanura*). Male and female bellbirds use song for resource defence against intra-sexual rivals, including mates and territories. However, females have a smaller syllable repertoire compared to males. This indicates that there may be sex differences in patterns of song sharing and diversity.

We propose that proximity predicts syllable sharing for both males and females, so that birds in adjacent territories share more syllable types with each other than with birds from distant territories. This would infer that bellbirds have micro-geographic song dialects, and it's possible that this pattern may be more apparent in males than in females since females sing fewer syllable types. Alternatively, bellbirds may show no differentiation in syllable types across the island if syllable sharing with neighbours is comparable with birds from distant territories. This would infer that bellbirds do not display song dialects at this spatial level. Examining micro-geographic spatial patterns of syllable sharing for both sexes provides further understanding on song sex differences and the roles of sex and social dynamics in shaping song dialects.

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Squirrel monkeys individuate object based on spatio-temporal information

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Human infants, apes, macaques, and capuchin monkeys can individuate objects, namely identify and track objects, based on spatio-temporal information. The current study further investigates the evolutionary origins of object individuation by testing squirrel monkeys (*Saimiri sciureus*). In Experiment 1, the subjects manually or visually accessed a box to find a surreptitiously pre-baited food item after seeing either one (expected condition) or two (unexpected condition) food item(s) dropped into the box. Squirrel monkeys (n=19) didn't look longer (Wilcoxon signed-rank test, z=0.980, n=18, p=0.327) nor search more (z=1.222, n=17, p=0.222) when the outcome violated their expectation. Experiment 2 investigates squirrel monkeys' competence with a more sensitive design, in which the monkeys searched food behind two small barriers rather than in a large box. The monkeys watched food item(s) being moved around two barriers along continuous path (suggesting one object) or discontinuous path (suggesting two objects). Then they could knocked down the barrier(s) to find the hidden food. The squirrel monkeys (n = 16) searched both locations within 20 seconds regardless, showing a ceiling effect on total searching behaviour. However, in the continuous/one-object trials they preferred to knock down first the last barrier where the food item disappeared, while they chose randomly in the discontinuous/two-object trials (main effect of path continuity: F(1, 15)=33.601, p<0.001, p2=0.691). This result reveals squirrel monkeys can demonstrate the ability to individuate objects with spatio-temporal information only when testing their preference but not their searching time, supporting the notion that spatiotemporal object individuation is likely a primate primitive trait.

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Sympathy in wild corvids: do jackdaws console stressed partners?

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Consolation behaviour is a type of sympathetic concern, where individuals attempt to decrease the stress levels of a conspecific through affiliation after a stressful event. It is often measured in a post-conflict context, where elevated affiliation from a bystander to a participant in a fight is interpreted as consolation. Understanding whether the bystander is truly showing consolation requires that the individual's own stress level is known (i.e. could the bystander merely be alleviating its own distress?) and that directionality of the interaction is known (is the consolation event unsolicited by the other individual?). Many studies only partially meet these criteria. Furthermore many studies, especially those on birds, are conducted in captivity, leaving a gap in knowledge about consolation behaviours in the wild. In this study, we used a ringed population of wild jackdaws to test whether individuals who had not experienced a stressor showed consolation behaviours to a stressed individual. To do this, we exposed incubating female jackdaws to a mild and ecologically relevant stressor while their male partner was absent from the nestbox. We then measured the level of affiliative behaviour directed from the male to the female upon his return, and compared this to baseline levels of affiliation. If consolation is found to occur, this will be some of the first evidence to show sympathetic concern in birds without the potential caveats of solicited affiliation and self-comforting behaviour. If it is not found, this study will nonetheless add valuable information about the function of consolation in wild animals. (Results due in June 2019)

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Individual differences in spatial memory predict changes in speed and straightness of transitory paths in the pheasant

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Spatial memory has been hypothesised to be an important determinant of an animal's movement decisions. Utilising memory allows an individual to build more efficient trajectories and reduce time in areas with high predation risk or low energetic yield. Yet individuals can differ in their ability to collect, store and utilise information about their environment. Although work on species with obvious sex differences in their spatial ecology indicate a strong, positive link between performance on cognitive tasks and space use and/or environmental complexity, individual level differences have had surprisingly little attention. We assayed the cognitive ability of 62 pheasant chicks using an associative learning task and a spatial memory task. We then released the birds at 10 weeks old into a woodland/grassland area in rural South-West England and monitored their movements with a reverse-GPS system. Using a hidden Markov model, we classified movement trajectories into three classes: resting/vigilant, foraging and transit between patches. We found that the proportion of time in transit per day is a repeatable within an individual and we discuss the potential for individual movement specialisations in pheasants. We then assessed whether an individual's performance on abstract cognitive tasks predicted temporal or spatial aspects of their movements. The implementation of state-of-the-art tracking technology on a large sample of individuals allows us to develop a deeper understanding of the interplay between spatial ecology and cognition.

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The genetics of visual preferences in a hybrid species

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Speciation in the face of gene flow is facilitated by linkage of traits under divergent ecological selection and those that contribute to assortative mating. The Neotropical butterfly *Heliconius heurippa* is one of the best-known examples of hybrid speciation. Specifically, its combined red-yellow forewing pattern is thought to have arisen as a result of hybridisation between the red patterned *H. m. melpomene* and yellow patterned *H. timareta linaresi*. The warning patterns of *Heliconius* are also known to act as mate recognition cues. We present data from mate preference experiments including over 1000h of video footage processed with a novel video analyses pipeline. Our data reveal that *H. heurippa* males show a preference for females that share its own red and yellow colour pattern, over that of *H. timareta linaresi* (which lacks the red forewing band). Preliminary analysis also provide evidence that a locus underlying this behavioural shift is physically linked to optix, which is responsible for the presence or absence of the red forewing band. This mirrors previous work showing the existence of a major preference allele for red patterns associated with optix in *H. melpomene*. Together, these data suggest that during the evolution of *H. heurippa*, both colour pattern and preference alleles were acquired through introgression from *H. melpomene*, which would facilitate hybrid speciation.

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The History of the Handicap Principle

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The most cited explanation for the evolution of honest signaling is Zahavi's Handicap Principle, and yet there is no consensus for how to define or test this idea. We provide a critical overview of the theoretical development of the Handicap Principle to show how it has generated confusion. Zahavi originally argued that honesty signals evolve because they are costly to produce. He also argued that honest signals evolve because they are wasteful, and that they evolve through signal selection, which favors wastefulness rather than efficiency. Zahavi's proposals for his Handicap Principle would have been rejected, except that he also suggested a logical explanation for reliable signals: he proposed that signals are honest because high-quality signalers pay lower viability costs for signalling compared to low-quality signalers. His two hypotheses were widely confused with each other and equated to good-genes models of sexual selection. Grafen's strategic choice model provided support for Zahavi's second hypothesis, but rather than being recognized as a Darwinian alternative to the Handicap Principle, it was misinterpreted as validating this illogical proposal. This model is neither a handicap model, nor a general principle for honest signalling. It is better interpreted in the framework of evolutionary life-history theory, and the Handicap Principle should be ushered into an "honorable retirement".

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The role of relatedness and familiarity in the social relationships of male Assamese macaques

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Male Assamese macaques are unusual among dispersing male primates as they form strong stable bonds with a few of their competitors in the group. Closely bonded males can act as allies during conflicts, allowing them to raise in dominance rank, which in turn increases their reproductive success. Here we assess the effect of relatedness (both maternal and paternal) as well as familiarity on the social behavior of wild adult male Assamese macaques at the Phu Khieo Wildlife Sanctuary, Thailand. We genotyped all 136 adult individuals of four multimale-multifemale groups at 17 microsatellite loci to assign kinship. This was combined with two years of observational data (4543h) on affiliative and agonistic social behavior for the up to 31 adult males of the groups. We find that strong bonds are not limited to closely related males, a pattern that has been reported in males of several other primate species. Since males leave their natal group before reaching sexual maturity, they also leave the majority of their close kin behind, which could explain why they turn towards unrelated individuals. Moreover, the coalitions that bonded males form benefit both males mutually, making the indirect benefits of bonding with kin of secondary importance to the direct benefits they get out of it. Overall, these results show that close affiliative relationships observed among male Assamese macaques are equivalent to human friendships in the sense that they develop between unrelated males.

Tolerant birds: Testing for inequity aversion in four parrot species

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Inequity aversion, the negative reaction to unequal treatment, is considered a basic mechanism of cooperative behaviour. However, this might only be adaptive for species, which can easily change cooperative partners. Utilizing a comparative approach, inequity aversion has been assessed in many mammalian species and recently also in corvids and a parrot species, revealing mixed results.

We tested four parrot species in a token exchange paradigm, in which we varied the quality of rewards delivered to the birds, as well as the effort required to obtain a reward. Results reveal that blue-headed macaws and African grey parrots did not show any reaction to being rewarded unequally. In contrast, the bigger macaws refused to exchange tokens, if their partner received a reward of better quality than they did. While the behaviour of the blue-throated macaws can be explained by motivation effects, as they refused to work for the LQR altogether, the great green macaws exchanged fewer tokens in the unequal compared to both equal conditions. Nonetheless, they also refused to exchange in a non-social control, in which the high-quality reward was delivered to their empty neighbour compartment; thus, indicating that frustration over not getting the better reward might be the underlying motivation for their refusal to exchange, rather than social comparison. None of the species were sensitive to inequity in terms of effort. Potentially, parrots do not exhibit inequity aversion due to interdependence on their life-long partner and the high costs associated with finding a new partner.

Traffic disturbance on the personality of tungara frog (*Engystomops pustulosus*) tadpoles in Trinidad

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Investigating how urban and disturbed environments impact key behaviour traits is important in understanding how animals will continue to cope with ongoing urbanisation. This is especially important in tropical habitats with high rates of development. Human disturbed environments place novel selection pressures such as habitat transformation, vehicle traffic, chemical pollutants and increased episodes of physical disturbance on animals. Increased levels of disturbance can impact on the personality (consistency of a behavioural trait) of animals. For example, individuals of the same species inhabiting high disturbance areas show increased levels of aggression and boldness. High disturbance locations have also been associated with individuals displaying increased flexibility in their behaviour, reducing how consistently the level of a behaviour will be displayed in an individual. However previous research has focused on adults which have developed within disturbed habitats and there has been limited research on whether differences in personality traits develop when individuals are reared outside their site of origin. In this study we looked at the impact traffic disturbance had on *Engystomops pustulosus* tadpoles in Trinidad. We collected eggs from 39 high or low traffic disturbed sites and raised the tadpoles within a field station under common conditions. We recorded activity, exploration and neophobia behaviours in 129 tadpoles and investigated how the disturbance levels from a tadpole's site of origin impacted these behavioural traits. We repeated each assay six times to additionally identify how consistently these behaviours were expressed in tadpoles from high and low disturbance areas.

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Wavering Behaviour in Chimpanzees

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As humans, we are aware of when we find things difficult. Although these experiences are not directly measurable, there are certain signature behaviours which coincide with self-reported task difficulty, such as motor hesitation and increased response latencies (Questienne, Atas, Burle, & Gevers, 2017). In non-human primates, metacognitive appraisals of this kind can only be assessed with purely non-verbal measures, such as choosing to opt-out of difficult trials and seeking additional information (Beran, Smith, Redford, & Washburn, 2006; Call & Carpenter, 2001). Such behaviour may indicate monitoring of task difficulty. In the current study we pursue a complementary approach by investigating whether objective task difficulty was related to hesitation behaviour ("wavering"), one of the behavioural correlates of difficulty experience in humans, in a sample of three chimpanzees who completed a serial learning task. After learning to clear five items in the correct order on a touchscreen, subjects were presented with subsets of two items from the list to see if they could infer their correct order. Previous research has established that these subsets vary in difficulty based on the items' positions in the original list (D'Amato & Colombo, 1988). All chimpanzees showed longer reaction times and increased frequencies of wavering behaviour in trials that were objectively more difficult. Chimpanzees therefore demonstrated a signature behaviour which is associated with humans' subjective experiences of difficulty and demonstrated this behaviour more often in trials of greater difficulty.

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A look in the mirror: What's this uncanny pigeon doing?

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Mirror self-recognition is a characteristic of higher intelligence, hence limited to a few animal species. Compared with humans and some great apes, monkeys fail at mirror self-recognition tests, and perceive their reflection as an 'uncanny' individual rather than a congener. Uncanniness results from the perfect synchrony between the monkey's movements and its reflection. Pigeons also have no self-recognition, but how they perceive their mirror image is unknown. Our study examined pigeons' responses to a mirror image versus a real pigeon. In both cases, the pigeons were exposed to two conditions: one consisted of approaching a feeder placed in front of a mirror or in front of a real pigeon behind a Plexiglas panel; the other consisted of approaching a feeder placed on the opposite side of the mirror or of the real pigeon. Our results show that the time latency to reach the food was significantly increased when the feeder was placed in front of the mirror rather than the real pigeon. Additionally, the number of pecking bouts and the total number of pecks at the feeder were considerably smaller in front of the mirror rather than the real pigeon. In conclusion, pigeons seem to be afraid by their mirror image, suggesting that they perceive, like monkeys, their reflection as an 'uncanny' individual rather than a congener.

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A new note in an old tune: Drosophila song and the drivers of behavior

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Deciphering how brains generate behavior depends critically on an accurate description of behavior. If distinct behaviors are lumped together, separate modes of brain activity can be wrongly attributed to the same behavior. Alternatively, if a single behavior is split into two, the same neural activity can appear to produce different behaviors.

Here, we address this issue in the context of acoustic communication in Drosophila. During courtship, males vibrate their wings to generate time-varying songs, and females evaluate songs to inform mating decisions. For 50 years, *Drosophila melanogaster* song was thought to consist of only two modes, sine and pulse, but using unsupervised classification methods on large datasets of song recordings, we now establish the existence of at least three song modes: two distinct pulse types, along with a single sine mode.

We show how this seemingly subtle distinction affects our interpretation of the mechanisms underlying song production and perception. Specifically, we show that visual feedback influences the probability of producing each song mode and that male song mode choice affects female responses and contributes to modulating his song amplitude with distance. At the neural level, we demonstrate how the activity of four separate neuron types within the fly's song pathway differentially affects the probability of producing each song mode. Our results highlight the importance of carefully segmenting behavior to map the underlying sensory, neural, and genetic mechanisms.

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Criss-crossing the frontier between behavioural game theory and conservation ecology

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Understanding the causes of the structure and dynamics of food webs is crucial for developing policies to halt the loss of biodiversity. Game theory could enable the prediction of links in webs as the outcomes of competitive games among species, and thereby help understand the consequences of environmental change. I focus on one example: the potential for loss of nest sites to cause great variation in the declines of closely-related species. I used a mathematical model to predict how a reduction in nest sites would affect species of different sizes and timing of nest establishment, and found that data on 43 bumblebee species and 221 bird species worldwide agreed with the model's predictions. This means that behaviour that evolved when nest sites were not hard to find could result in some species may be driving others to extinction due to habitat loss. This phenomenon – anthropogenic competition – is likely to occur for any formerly abundant resources that suddenly, on an evolutionary timescale, are now limiting population sizes. Furthermore, these data provide rare quantitative support for the predictions of the theory of animal conflict, revealing the benefits of criss-crossing frontiers between ecological disciplines.

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African grey parrots behave more pro-socially when not rewarded themselves

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Prosociality is defined as a voluntary, typically low-cost behaviour that benefits another individual. Parrots are interesting models to study such other-regarding behaviours, given their social complexity, their enlarged brains and their surprising cognitive capacity. We assessed African grey parrots' prosocial tendencies in dyadic settings implementing two different methodologies. In the prosocial choice task based on token exchange, an increasingly widely used comparative paradigm, the parrots only behaved prosocially, choosing a prosocial token (rewarding both birds in the dyad) over a selfish token (rewarding only the actor), when they were tested in the active and passive role alternatingly. The birds also increased their willingness to provision food to their partner, if it was of higher quality than that the actor obtained. Nonetheless, the control conditions suggest that the parrots had not fully understood the task's contingencies. When tested in a token transfer paradigm, in which the subject had tokens that only its neighbour could exchange for food, the grey parrots actively transferred tokens to their partner. In control conditions, in which no partner was present (non-social control) or in which the partner was present but could not exchange either, they transferred significantly less tokens into their neighbour's compartment than in the test. The results of the two studies raise the possibility that other-regarding tendencies may be partially masked if the subjects need to consider their own and another's payoff simultaneously. This confounding effect may similarly apply to other species and should be examined and considered by future comparative studies.

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Androstenone induces submissive behavior of horses thorough OR7D4 expressed in VNO and nasal cavity tissues

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Androstenone is a steroidal pheromone found in the saliva of boars. Androstenone is an intermone that elicits a response in different species. OR7D4 is an odorant receptor that responds to androstenone. The main objectives of this study were 1) to investigate expression of OR7D4 in horse vomeronasal organ (VNO) and olfactory epithelium tissue and 2) to evaluate the effect of androstenone on horse behavior. Tissue samples were collected from VNO and nasal cavity of two Thoroughbred horses. The expression of OR7D4 was determined using immunohistochemistry and western blot. For the 1st behavior test, 15 horses were used with 3x3 Latin square study design. For each group of horse, 2ml of 0.1 or 1 ug/ml of androstenone diluted with jojoba oil or oil only (control) were applied around muzzle of horses. Five mins after application, a handler slightly push down horse's head under horizontal level and timed for 5 secs (submissive behavior). The time for showing the first submissive behavior was recorded. For the 2nd test, 15 horses were used to test the effect of 10 ug/ml of androstenone in submissive response of horses with cross-over study design. Neurons and cells of VNO and nasal cavity tissues were immunolabeled with OR7D4 antibody. Treatment with 10 ug/ml of androstenone applied 30 min prior to the test significantly decreased time to show submissive behavior compared with control. In conclusion, androstenone appears to induce submissive behavior of horses throughout OR7D4 receptor expressed in VNO and olfactory epithelium tissues.

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Animal habitat networks: why should we care and how can we model them?

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Animals live on habitats, the physical configuration and structure of which can shape individual movements thus can mediate the downstream ecological and evolutionary processes. Network theory has long been applied to discuss habitat connectivity and animal movements across contexts, but there is still a lack of a general framework for modelling the physical configuration and structure of animal habitats using networks. Animal habitat networks are abstractions of habitat entities, and their properties are expected to be shaped by features of physical environments; yet the properties of animal habitat networks remain largely undiscussed. We propose a general framework for modelling the physical structure and configuration of animal habitats using networks and a general model for depicting animal habitats; then we explore the properties of animal habitat networks with our model. We highlight the application of our framework and model for explicitly describing the physical configuration and feature of animal habitats in studies of animal ecology, evolution and conservation.

Anti-predator behavior in male bushcrickets is adapted to threat and age to optimize reproductive success

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Animals regularly trade off vital activities, such as attracting potential mates against avoiding predators. Many males attract females by species-specific calls, which also attract eavesdropping predators. Males are thus under strong selection pressure to trade-off singing (mate attraction) with stopping to sing (predator avoidance). Moreover, the life of many animals is short, and the likelihood to obtain a future mating decreases over a mating season. We thus hypothesized that male decision making changes over the lifespan to optimize reproductive success: males should prioritize predator avoidance over mating effort early in the mating season, yet accept higher predation risk towards the end of the mating season. We tested this hypothesis in singing male *Tettigonia viridissima* bushcrickets (Orthoptera: Tettigonidae), whose song attracts both females and eavesdropping predatory bats. We conducted playback experiments with individual wild caught male *Tettigonia viridissima*, testing each male twice during the mating season. Our playbacks mimicked three levels of bat predation threat by varying the sound level and call repetition rate of the presented bat echolocation calls. We recorded the bushcrickets' song and analyzed the proportion of reacting males, the time until and duration of song cessation as a function of simulated predation threat and male age. At high and intermediate predation threat, young and old males reacted very similar. At low predation threat, however, old males stopped singing less often, and stopped later and for shorter periods than young males. Decision making in bushcrickets is thus adapted to predation threat and age, to optimize reproductive success.

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Bats integrate information about species identity, conspecific activity, and prey abundance when eavesdropping

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Animals can use Inadvertent Social Information (ISI) to improve fitness-relevant decisions. Since bats emit high-amplitude species-specific echolocation calls when flying, they provide a constant flow of ISI to others. Of particular interest is the feeding buzz rate - characteristic call sequences preceding any prey capture - which correlates with insect abundance. Our goal was to systematically test which ISI bats integrate when eavesdropping on others and how this integration affects space-use and interactions, respectively.

We used a community-wide approach and investigated the effects of a broad range of playback feeding buzz rates and conspecific activity on eavesdropping responses in 24 bat species combinations in the wild.

For the first time, we reveal that finely graded and density-dependent eavesdropping responses are not limited to particular foraging styles or call types, but instead are ubiquitous among insectivorous bats. All bats integrated ISI about calling species identity, prey abundance, and conspecific activity to estimate the cost-benefit ratio of prospective interactions, yet in a species-specific manner. The effect of buzz rate was multifaceted, as bats responded differently to different buzz rates and responses were additionally modulated by heterospecific recognition. Conspecific activity had a negative effect on the eavesdropping responses of all bats.

These findings can explain the inconsistent results of previous studies and advance our understanding of the complex nature of con- and heterospecific interactions within bat communities. A comprehensive understanding of how bats incorporate social information into their decision-making will help researchers to explain species distribution patterns and eventually to unravel mechanisms of species coexistence.

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Behavioral pattern of unique and only Black Colored meat variety of India (Kadaknath)

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Kadaknath is only Black Meat Chicken (B.M.C.) Breed of India also called as Lamborghini of chicken birds. It is a native bird of Madhya Pradesh, reared mainly by the tribal communities of Bhil and Bhilala. The Kadaknath is, of course, not the only black chicken in the world. China has the Silkie chicken and Indonesia the Avam Cemani. Adult plumage varies from silver and gold-spangled to bluish-black without any spangling. The skin, beak, shanks, toes and soles of feet are slate like in colour. The comb, wattles and tongue are purple. Most of the internal organs show intense black coloration, which is pronounced in trachea, thoracic and abdominal air-sacs, gonads and at the base of the heart and mesentery. The blood is darker than normal. The black pigment is the result of melanin deposition. Kadaknath has special medicinal value in homeopathy and a particular nervous disorder and have lowest cholesterol level than any other chicken variety. The study was carried out to understand the behavior pattern of these unique birds in open and closed shed system. The birds were divided in to 3 groups of 50 birds each. T1 birds were reared in shed for whole time,T2 birds were kept open during day time and kept in shed at night,T3 birds were kept in open condition throughout the day and night. A number of behavioral and production pattern were studied like pecking, foraging, cannibalism, egg production, weight gain, sunlight exposure, effect of feeding time, feed consumption, feed conversion ratio. It was observed that birds kept in open during day and then kept in cages at night gave best production results like egg production, weight gain, age at first laying etc. Cannibalism and Pecking was most common in T1 group kept in sheds and was least in T3 birds. It was also observed that women farmers are best suited for backyard poultry farming and if Kadaknath birds are given proper popularization they can prove to a be good source of income generation for the poor women farmers because of their unique colour and taste. These birds can generate a price of about 300 times more than normal birds

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Behavioural ecotoxicology of colour change

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The brown shrimp, *Crangon crangon* utilizes chromatophores (specialized cells containing pigments) to match its background, changing its colour from pale (pigments contracted) to dark (pigments expanded) to become almost invisible in its environment. Chromatophores also protect the shrimp (at least in the larval stages) from UV light. The control of pigments depends on hormones, secreted by the shrimp as a response to different stimuli (e.g., light, temperature and colour of substrate). Heavy metals are found often and consistently in estuaries, due to human activities along the coasts and can potentially affect behavioural responses, acting as anthropogenic stressors. Detecting the concentration of pollutants in the aquatic environment is challenging (because of spatial and temporal variation) and often not sufficient to assess the actual effects on marine organisms. The use of colour change as a behavioural marker of pollution can become an effective tool to assess the initial stages of biological alteration in aquatic organisms. To test the efficiency of this novel technique, brown shrimp have been treated with non-lethal concentrations of heavy metals. Shrimp subjected to cadmium became darker, suggesting a stress response. Arsenic did not produce such effect, possibly due to the ability of marine organisms to biotrasform inorganic arsenic into the less toxic organic form. Thus, colour change can be a promising effective tool for behavioural ecotoxicology studies.

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Behavioural repertoire and associated vocalizations in a social passerine, Jungle Babbler (*Turdoides striata*)

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Animals display a wide variety of behaviours across different environmental and social contexts within their lifetime. In this regard, long-lived social birds with their vast repertoire of solitary as well as interactive behaviours, provide a fascinating system to study the ontogeny, function and evolution of behaviours. Social birds also show well-developed vocal communication between group members. As communication plays a critical role in maintaining social bonds, examining the diversity and function of these vocalizations helps in achieving a better understanding of the organism's social complexity. This study aims to describe the behavioural and vocal repertoire of a social passerine, Jungle Babbler (*Turdoides striata*). Jungle Babblers (JB) are a cooperative breeding bird found in groups of 3-20 individuals. The present study describes 13 distinct behaviours in JB wherein some behaviours showed a specific temporal pattern of occurrence at both diel and seasonal scales, while foraging occurred throughout the day and year with similar frequency. In addition, ten different calls associated with different behavioural contexts were recorded and characterised acoustically. This study presents the first quantitative description of the calls of this social passerine. It also lays the foundation for further studies examining the role of social complexity in the evolution of acoustic complexity.

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Bird flight speed depends on the climb rate

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The extent to which animals modulate their movement decisions to minimise their energy expenditure remains an active area of research. This has been tested widely for flying animals, because the power curve leads to specific predictions about the flight speeds that animals should adopt in different scenarios. Nonetheless, this model is designed for level flight and does not explain the high variability in flight speeds often observed in powered flight. We equipped homing pigeons (*Columba livia*) with 1 Hz GPSs to examine the extent to which flapping birds vary their flight speed in relation to their climb rate and the influence of environmental factors on their flight altitude. We found that the airspeed was extremely variable, with a range of 10.9 m s-1 within flights. Airspeed was negatively correlated to the climb rate, increasing during the descent and decreasing during the ascent. However, birds were not maintaining a constant power output across periods of ascending and descending flight. This was evident as the slope of the relationship between the power required to climb and the power required to change speed was less than one, and furthermore, the slope was greater during periods of descent. The flight altitude depended on the topography of the route. Overall, this demonstrates that the vertical flight path has an important influence on speed selection in birds and that this must be considered when modelling the implications of flight speed for energy expenditure.

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Born to be asocial: Newly-hatched tortoises spontaneously avoid unfamiliar individuals

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Individual recognition is important for modulating social interactions, but it is not clear whether it is innate or to what extent it depends on experience, and whether it is present in species with limited social habits, such as tortoises. In wild tortoises, evidence of social interactions is limited to behaviors performed years after hatching, in the context of mating. To investigate the presence of abilities of individual recognition at the onset of life in tortoises, we used hatchlings of two species (*Testudo marginata*, *Testudo graeca*) reared with a single conspecific as unique social experience. When located in a novel environment together with the familiar conspecific, tortoises reached the average distance expected by random trajectories. On the contrary, tortoises tested with an unfamiliar conspecific first explored the mate, then actively kept a distance significantly larger than expected by chance. These results show spontaneous abilities of individual recognition in a non-social species at the onset of life, and active avoidance of unfamiliar conspecifics. We suggest that this predisposed behavior might be adaptive for young tortoises' dispersal and that evolutionary pressures for social behavior might be relevant for non-social species even at the onset of life.

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Bottlenecks in juvenile snapper (*Chrysophrys auratus*).

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Sparid Snapper (*Chrysophrys auratus*) are in important commercial and recreational species in New Zealand that have been under intense fishing pressure over many decades. Adult stocks are now well under fisheries targets: In this study we hypothesize that this, in part, may be due to habitat bottlenecks acting within the critical first few months of life when juveniles are reliant on sheltered nursery habitats and particularly structured environments. This study investigates how the territorial behavior of juvenile snapper may set a carrying capacity on nursery habitats that is well below any upper limits set by availability of food or shelter. Here we investigate firstly the stability of dominance hierarchies within groups of juveniles, and secondly the factors driving such dominance hierarchies. Specifically, we address the relative importance of size, prior residency, and personality (boldness) in determining the outcome of paired contests between juveniles. We further discuss the relevance of these findings in terms of fisheries and environmental management.

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Collective decision making by rational individuals

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The patterns and mechanisms of collective decision making in humans and animals have attracted both empirical and theoretical attention. Of particular interest has been the variety of social feedback rules and the extent to which these behavioural rules can be explained and predicted from theories of rational estimation and decision making. However, models that aim to model the full range of social information use have incorporated ad hoc departures from rational decision-making theory to explain the apparent stochasticity and variability of behaviour. I will describe a model of social information use and collective decision making by fully rational agents that reveals how a wide range of apparently stochastic social decision rules emerge from fundamental information asymmetries both between individuals and between the decision makers and the observer of those decisions. Using this model I will show how rational decision making creates complex dependencies between the environment, experimental conditions, population structure and observable social behaviour.

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Communicative value and intentional use of facial expressions in red-capped mangabeys (*Cercocebus torquatus*)

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Facial expressions in primates have often been qualified as involuntary markers of emotional state. While the dual intentional and emotional use of facial expressions has been recently suggested for the apes, the question whether monkeys produce facial expressions intentionally to communicate remains open. Here, we tested whether red-capped mangabeys (*Cercocebus torquatus*) use facial displays socially and concomitantly to behavioural markers of intentional communication commonly used in gestural studies. These intentional markers are based on the assumption that a signal produced intentionally in dyadic communication would (i) be directed to a recipient, (ii) have the function to reach a specific goal, and (iii) lead to a change in the recipient's behaviour. We described six facial expressions that were used in social contexts by captive red-capped mangabeys. Those implied ears, eyebrows and mouth movements, that could be graded in intensity and produced either independently or combined with one another. We found that five of the facial expressions described could be associated in some cases to all the behavioural markers of intentionality. However, only "open mouth" displays, produced in playful contexts, were found to be associated to intentional markers in most of the cases. Other facial expressions were at least directed to a recipient, except for yawns, that seemed to be disentangled from dyadic communication. Taken together, these results suggest a communicative value of some facial expressions in red-capped mangabeys, but reveal substantial variability in their intentional use.

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Comparative Acceleration Study Across Fish Phylogeny

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Undulation of the axial body is the fundamental motor pattern in vertebrates that predates the origin of paired fins and jaws, and it has powered the locomotion of the earliest animals with backbones. Over the past several decades, a number of studies on fishes have investigated the kinematics, physiology and hydrodynamic mechanisms of undulatory locomotion during steady swimming. In contrast, far less is known about how these mechanisms apply to unsteady locomotion; for instance, when fishes accelerate quickly to catch a prey or avoid predators. Here, we leverage a multi-disciplinary approach to study forward acceleration. Our initial flow tank experiments using live rainbow trout showed that during acceleration tail beat amplitude is approximately 30% higher than during steady swimming. To uncover how elevated tail beat amplitude relates to thrust production and propulsive efficiency we used a combination of flow visualization experiments on trout and soft-bodied biomimetic models. Our results reveal that by increasing tail beat amplitude fish are able to enhance thrust production through alteration of the vortex ring geometry generated by the caudal fin. We suggest that this phenomenon is generalized to all fishes, given that we later observed similar acceleration kinematics in more than 50 species with vastly different body shapes, swimming modes and ecological habitats.

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Collective action modulates androgen levels in shoaling fish

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Androgens, traditionally viewed as hormones that regulate reproduction in male vertebrates, are often modulated by social stimuli. High levels of the 'social hormone' testosterone (T) are linked to aggression, dominance, and competition. Low T levels, in contrast, promote prosocial behaviours such as affiliation, social tolerance, and cooperation, which can be crucial for group-level, collective behaviours. Here, we test the hypothesis that, in a collective context, low T levels should be favourable, using male and female stickleback fish (*Gasterosteus aculeatus*) and non-invasive waterborne hormone analysis. In line with our predictions, we show that the fishes' T levels decreased significantly during shoaling, with high-T individuals showing the largest decrease. Ruling out stress-induced T suppression and increased aromatase activity, we find evidence that shoaling directly inhibits androgen responsiveness. We also show that groups characterized by lower mean T exhibit less hierarchical leader-follower dynamics, suggesting that low T promotes egalitarianism. Overall, we show that collective action results in reduced T levels, which may serve to promote coordination and group performance. Our study, together with recent complementary findings in humans, emphasizes the importance of low T for the expression of prosocial behaviour in vertebrates suggesting a deep evolutionary history.

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Considerations used by desert isopods to assess scorpion predation risk

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Animals adjust behaviors to balance changes in predation risk against other vital needs. Animals must therefore collect sensory information and use complex risk assessment process that estimates risks and weigh costs and benefits entailed in different reactions. Studying this cognitive process is challenging, especially in nature because it requires inferring sensory abilities and conscious decisions from behavioral reactions. Our goal was to address this empirical challenge by implementing psychophysical principles to field research that explores considerations used by desert isopods (*Hemilepistus reaumuri*) to assess the risk of scorpions that hunt exclusively from within their burrows. We introduced various combinations of chemical and physical cues to the vicinity of isopod burrows and recorded their detailed reactions upon first encountering the cues. The isopods reacted defensively to scorpion odor but only when accompanied with excavated-soil or other odors typically found near scorpion burrows. Isopods also reacted defensively to piles of excavated soil without scorpion olfactory cues, suggesting that isopods take precautions even against physical disturbances that do not necessarily reflect predator activity. Simultaneous presence of different cues provoked graded responses, possibly reflecting an additive increase in risk estimation. We conclude that wild isopods use defensive reactions toward environmental signals only when the integrated perceptual information implies an active scorpion burrow, or when they lack data to refute this possibility.

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Cooperation of shrikes and barred warblers during the nest defence?

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The barred warbler has been repeatedly shown to nest in the proximity of shrikes. We tested the hypothesis that barred warblers breed close to shrikes to profit from their very active nest defence against predators. Moreover, we tested if they consider shrikes to be potential predators of barred warblers as well (umbrella protection). We presented dummies of avian predators differing in the threat they represent to the nest and to adult barred warblers, at nests of barred warbler, which do and do not breed in association with shrikes. We showed that the intensity of the antipredatory behaviour of barred warblers is equal to all predators (jay, magpie, sparrowhawk), but they tend not to approach the sparrowhawk, which is capable of catching the adult bird. Barred warblers intensively warned also in the presence of magpie, which is never attacked by shrikes. The dummy of shrike elicited less alarm calling than the control pigeon, barred warblers commonly approached it and provided food to chicks. Barred warblers obviously do not considered the shrike to be a potential predator. The close presence of shrike nest did not affect the barred warbler alarm calling to any dummy. Even the presence of adult shrikes at the barred warbler nest during the experiment did not induce a more intense alarm calling of the barred warblers. We may conclude that we were not able to confirm any adaptive function of the close breeding of these two species.

Coping with habitat uncertainty: a case study with pond breeding dragonflies

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The Guiana shield is one of the most ancient bedrock formations on Earth that houses a variety of ecosystems including forests, floodplain savannas, and granite outcrops (inselbergs). On these inselbergs, eroded depressions house temporary rock pools. The fauna of these habitats in South America is just recently described and the underlying processes that determine survivorship of species in this changing habitat are not well understood.

For these reasons, we are investigating some important behavioral adaptations that can explain the survival of odonate larvae in the unpredictable environment of temporary rock pools. We are using common garden experiments to test the relative importance of water level reduction and increased conductivity (due to evaporation in natural conditions) as cues that can stimulate faster development and shorter times to metamorphosis of last instar larvae. We test whether this type of phenotypic plasticity is more developed in species from the family Libellulidae, comparing between them, and with Aeshnidae species, which have longer aquatic life phases. We have also established species life cycles timing, rearing individuals from earlier stages using controlled conditions with aquatic parameters measured from their natural environments; then, we also include the effect of average larvae survival without any treatment. As an additional means to escape from drying ponds, we investigate the ability of these dragonflies' larvae to reallocate in inundated pools when their habitat dries out. Using experimental arenas, we test to what extent visual cues, chemical cues, moisture, or terrain slope, can help them to find new suitable habitats.

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Development of an assessment tool to understand canine and feline behaviour and personality

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Understanding canine and feline behaviour and personality has important welfare implications. First, behaviour-related problems are major reasons for relinquishment and euthanasia. Second, environmental factors largely affect behaviour and thus, changes in daily lifestyle could improve welfare. Third, breed differences in behaviour and personality suggest genetic contributions that can reveal genes and molecular pathways to advance breeding programs and improve the treatment of problematic behaviour. Fourth, metabolomics studies could unfold metabolic fingerprints for diagnostics of behaviour problems. Finally, pets can serve as spontaneous models for human anxieties. A welfare assessment tool should be quick, reliable and user-friendly. As a part of our large pet behaviour project, we introduce here a novel interactive behaviour and personality survey for dogs and cats. With this tool we aim to collect a large epidemiological data (up to 100k) with a specific focus on the identification of potential behavioural indicators of welfare. Our survey has an automatic reporting system which gives immediate results to participants by generating a behavioural profile. This profile can be compared to other pets in the database. The breed organizations can utilize the breed-wide data for breeding. The current participation rate is > 1100 answers per month. Preliminary analysis of the data suggests breed differences in behaviour and personality, and high prevalence of behavioural problems. We expect to identify various environmental and lifestyle contributors affecting pet welfare.

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Directionality of heterospecific sociality in mixed-species flocks of songbirds

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Mixed-species groups are common among fish, birds, and mammals, and are generally thought to provide their members with anti-predator benefits and increased foraging efficiency. The evolutionary explanations for interspecies sociality focus on group-level benefits and species-level interactions, thus neglecting the potential for uneven competitive interactions and individual social preferences to play an important role in shaping mixed-species social structure. Here, we investigate how individual and social factors affect heterospecific mixing in winter foraging flocks of three tit species (*Paridae spp.*). We used a unique experimental setup that allowed us to manipulate foraging associations and to analyse active preference for potential flock members. We analyse individual grouping decisions of more than 400 PIT-tagged birds in different social scenarios. Individuals from all three species predominantly foraged in mixed-species flocks, instead of smaller single-species groups. Social choice data suggest that preferences for heterospecific flock members is predicted by dominance relationships between species, with more dominant species joining more individuals from more subordinate species. We discuss the mechanisms underlying individual social decisions, and their importance for understanding the organisation of heterogeneous groups and evolution of interspecies sociality.

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Distortion of perceived value perception in insects

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Making value judgements is critical to choosing between options. Traditional economic theory assumes that the value of an option depends solely on the state the option brings an actor to, and traditional theories of animal decision-making have followed this assumption. However, deviations from economic rationality have repeatedly been described in both human and animal behaviour. Rather than being fixed, value may be relative. We have found that value perception in insects can be distorted in many of the same ways as it is in humans and other vertebrates. Ants (*Lasius niger*) are shown to make value judgements relative to expectations. This demonstrates cognitive, not physiological, incentive contrast effects. We further show that perceived value can be affected by changes in expectation which are not related to option quality. Finally, we show that working harder for a reward makes the reward seem more valuable to foraging ants. Taken together, we show that many apparently irrational behaviours described from behavioural economics, consumer psychology, and vertebrate behaviour are mirrored in the behaviour of insects, raising questions about the evolutionary and neurological origins of these behaviours.

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Does sociality affect reproductive timing in a cooperative nursing system?

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We aim to understand whether social interactions prior to breeding determine female reproductive timing in a species that may breed year-round and with alternative female breeding tactics (solitary versus communal nursing). It is well understood that animals "match" the timing of when their resource requirements are highest (e.g. peak lactation) to the timing of when the quantity and quality of resources available also peaks (e.g. food availability). In social animals, the availability of social partners, particularly those that contribute to an individual's fitness by helping to rear young, may be considered an essential resource. Here, we analyzed whether social partner choice among adult females prior to breeding influences the timing of reproduction. Using RFID readers and genetic data from a long-term monitoring project on house mice (*Mus musculus domesticus*), we examined whether characteristics of a female's social group and potential female nursing partners influence the timing of birth and, as a result, a female's lifetime reproductive success.

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Ecological and Environmental Drivers of Polydomy in Ants

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Living in groups can improve a species' defence against predation. Polydomy, the state in which ants of a single colony occupy two or more nests, is hypothesised to have some defensive benefits in the face of predation. These benefits are hypothesised to be due to the persistence of the colony after the destruction of a nest (hypothesis 1), improved retaliation (hypothesis 2), the presence of nests to flee to if one nest is destroyed (hypothesis 3). I am investigating whether the proportion of polydomy in a model increases in relation to monodomy (the state in which a single colony occupies a single nest) under different predation regimes. These include varying numbers of ants lost by a predation event, and different preferences on the part of the predator for large or small nests.

Escaping from a predator: run for your life or take another look?

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It is now well understood that prey assess the risk levels associated with an approaching predator to make informative decisions on when to escape. However, little is known about subsequent decision-making process. For filling that knowledge gap, we approached corvids until they escaped, and then measured escape time. When birds were being followed during escape, escape times were the longest, escape trajectory was modified the most during escape, and a larger proportion of individuals changed from terrestrial to aerial escape type compared to observations where birds were not followed. While there were some interspecific differences, the general patterns indicated that birds dynamically assess risk during escape to find an optimal balance between being depredated and spending too much time and energy on escaping.

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Evolution of personality in cooperative breeders: boldness, prosociality and social strategies

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In cooperative breeders, subordinates may increase the dominants' reproductive success while reaping only limited direct fitness benefits. Crucially, not all subordinates benefit the breeder to the same extent because of between-individual variation in helping contributions, which may be linked to personality differences. Consequently, breeders should not only attempt to control the number of subordinate individuals joining their group, but should also be sensitive to their individual characteristics and to the current environmental conditions. Empirical studies have revealed variation within species in the caring effort of subordinate joiners and the rate of acceptance by the dominant. However, little is known about the link between personality traits and the social strategy of cooperative breeders. Using an individual-based model, we investigated the co-evolution of the two personality traits boldness and prosociality in populations of cooperative breeders where nest sites are limited. We assume that boldness increases the probability of subordinates to leave an occupied nest (thus looking for an opportunity to become dominant in the next season) and to engage in a fight. Prosociality increases helping effort as a subordinate, increases the probability to accept a submissive floater and decreases the probability to engage in a fight. We systematically varied the information available to the breeder, creating uncertainty about the efforts of others. Our results highlight the importance of taking into account individual variation, showing that the information animals process and the behavioural phenotypes influence group- and population-level phenomena.

Features orienting motor activity of rats after ligation of the common carotid arteries and intranasal application of stem cells

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The goal is to analyze the characteristics of the oriental motor activity of experimental animals after ligation of the common carotid arteries and the intranasal application of stem cells.

The experiments were performed on male Wistar rats (n = 15). The parameters of the tentative-motor activity of rats were assessed in an elevated plus maze using the ANY-Maze software package before ligation and 3 and 7 days after surgery. The general mobility, the motor activity of animals in open and closed sleeves, and the average speed of movement in the maze were recorded.

It was established that in animals on the third day after obturation of the common carotid arteries, the total distance covered (three times) and the distance covered in a closed area (twice), the number of mobility episodes (twice), the number and the duration of acts of verticalization (twice), the total distance covered in a closed area (twice), the average speed of movement in a closed area (twice), the total time of mobility in a closed area (three times), there was no visit to open areas the maze . The data obtained indicate a decrease in the orientational motor activity in laboratory animals after ligation of the common carotid arteries. These changes are saved both in the acute period (the third day) and in the more distant period (the seventh day) after the modeling of ischemic stroke. A different picture was observed in the group of animals that were obtruded by the common carotid arteries and intranasal administration of mesenchymal stem cells (MSC). On the third and on the seventh day after ligation of the common carotid arteries and the intranasal administration of MSCs in this group of animals compared with the initial value, there were no significant differences in the estimated motor activity in the elevated plus maze.

Thus, the introduction in the acute period after occlusion of the common carotid arteries the introduction of mesenchymal stem cells is accompanied by a more rapid recovery of the oriental-motor activity in experimental animals.

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Floater strategies in the spotless starling

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Nest-site limitations are an important constraint for hole-nesting birds. We studied a spotless starling (*Sturnus unicolor*) population in which the number of floaters exceeds nest site availability. By providing extra nest-boxes we found that floaters search for a nesting place throughout the breeding season until the very end of the second-broods, even though the chances of raising young successfully at that time are greatly reduced. Female floaters showed evidence of increased follicular development around the population laying peak, showing reproductive synchronization with female nest-owners, and suggesting a brood-parasitism strategy. We further studied movements of floaters by radio-tags and transponder readers, finding that they show limited home areas. This suggests that floaters settle in reduced areas within the colony, possibly as a way of acquiring public information about available nesting sites.

Foraging efficiency of a bat predator in acoustically complex environments

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Prey aggregates tend to attract predators as they become more conspicuous with increase in number. Such grouping however may benefit prey through a predator confusion effect, in which predators fail to efficiently single out a prey from an aggregate. Most studies across different taxa, including fish, reptiles and primates, have examined the confusion effect in the visual context, and not in the auditory context. Gleaning bats such as the lesser false vampire bat, *Megaderma spasma* that rely predominantly on prey-generated sound cues for localization, are appropriate model systems to test for an auditory confusion effect. We first examined if *M. spasma* was attracted to calling prey aggregates in a choice experiment, and then tested if the bat showed difficulty in localizing prey in an aggregate, using different experimental tasks. Habitat complexity via leaf clutter was also included to assess how vegetation might affect the bat's foraging efficiency. Preliminary results show that bats approached calling prey aggregates more often than prey calling alone indicating predator's preference to aggregate prey. In the experimental tasks, the bats took the least time to localize a lone calling prey. Increasing auditory complexity with calling aggregates, increased the average time taken to complete the foraging tasks suggesting an auditory confusion effect. These results also suggest a preference-complexity trade-off in bats when attacking calling prey aggregates.

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Genetic variation in plastic response to predation and its cost to reproduction

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Several studies have shown that genotypes differ in their phenotypic expression in different environment (G:E). This means that there is among-genotype variation in the level of plasticity, allowing for selection on plasticity. It also means that no individual is fully plastic, indicating that there are costs to plasticity. However, there is a lack of empirical data showing any cost of developing a plastic machinery. Moreover, the few studies that have tested for cost have tested the cost for differential expression of a trait rather than the cost of different investment in the plastic machinery. Here, I used multiple isogenic lines of *Gryllus sigullatus* to investigate the genetic variance in plasticity for response to predators and how level of plasticity affected reproductive output. Crickets from each line were run through an open field behavioral assay with and without predator cues present, where change in activity level between the two trials was used as a measurement of plasticity. Crickets with higher levels of plasticity were predicted to have lower fitness. Understanding the costs of plasticity can help us predict a population's ability to adapt to a changing environment.

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Horses are able to recognize a familiar human face in a photograph

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Facial recognition has been widely studied in primates, and also recently in other species such as dogs. In this experiment, we investigated whether horses could recognize the face of humans they were familiar with from their photograph. Eleven female horses were trained to recognize the faces of four people (recurrent faces) from novel faces displayed on a screen. They were rewarded when they touch the recurrent faces but never when they touched a novel face. These four people were unknown to the horses in real life, but their faces had become familiar during the training sessions. When horses choose the recurrent faces for more than 75% of the trials over two consecutive days, we tested whether they could spontaneously recognize the photograph of the face of their current handler. Horses recognized her in 0.71+0.18% of the trials without pre-training (comparison with chance level: $t=3.65$; $p<0.004$). The final test involved recognizing the photograph of a person the horses had not seen for 6 months. They recognized her in 0.77+-0.14% of the trials (comparison with chance level: $t=6.24$; $p<0.0001$). During a control trial, we also checked that animals did not use cues other than familiarities in real life when responding correctly. Overall, these results show that horses have advanced facial recognition abilities, and are able to recognize a face in a photograph, even when the face is not of their species. Moreover, they demonstrated a long term memory of human faces.

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How do seabirds prospect before establishing a new reproductive habitat?

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Territorial animals are permanently analyzing the neighbouring areas, looking for areas with high density of food, quiet areas to rest or potential reproductive habitats. From these, the latter becomes extremely important in scenarios where the current reproductive habitat is in risk due to internal or external perturbations.

We study this problem for the case of a seabirds colony in La Banya, Delta de l'Ebre. There, multiple factors as the intrusion of new predators or the modification of the territory have perturbed the colony. We analyze different features of the trajectories and model them to study which relevant magnitudes give us insights about the prospection of new reproductive habitats.

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Interactions between individual variation in behaviour and group performances in House Sparrow

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Social living strongly influences selection on individuals' traits, which in turn evolve to shape the social environment. Individuals in a group vary, and this variation creates social groups that differ from one another with respect to their collective performance and the distribution of resources and fitness of their members. Using captive house sparrows (*Passer domesticus*) we performed a series of experiments investigating the feedback between individual and group traits in situations particularly crucial to survival and fitness. i) Using a novel experimental design we investigated how two groups with different characteristics would exploit limited resources in a novel environment, i.e. if the amount of resources each individual consumed was going to depend on the groups' attributes. We discovered that belonging to the group of the first individual to exploit the resource was critical in determining the amount of resource consumed. ii) We tested house sparrow dyads during an open-field test and during a simulated predator attack. We discovered that individuals assuming the position of leaders and producers during the open-field test switched to being followers during the attack.

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Intraspecific movement specialisations and their implications for personality and movement ecology research

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Many animal personality traits have implicit movement-based definitions. It has therefore been proposed that movement studies could benefit by acknowledging and studying consistent individual differences, and, conversely, animal personality studies could adopt a more quantitative representation of movement patterns. We used high-resolution image-tracking to repeatedly record the movements of individual free-swimming three-spined stickleback fish (*Gasterosteus aculeatus*) in a simple environment that had either two, three or five shelters present. For each fish in each trial we investigate and link three standard movement parameters adopted from random walk theory and two broad movement descriptors used in animal personality studies. We found that all of our fish movement measures were highly consistent within individuals, but highly variable between individuals, representing intraspecific movement specialisations. Environmental differences did not explain variability in our sample. Fish movement parameters predicted personality measures. Movement parameters can therefore be viewed as "micro-personalities", representing the building blocks (behavioural mechanisms) that give rise to personality differences. For personality traits that have implicit movement-based definitions this finding suggests that standard movement parameters represent a short-term, easy assay of personality differences. The inter-individual consistency we observed in movement parameters and their links to personality have implications for understanding and modelling how individual movements scale to group-level processes, and future works should attempt to include individual heterogeneity in movement models.

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Jackdaws learn socially about dangerous people

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Social information can help animals to learn about novel threats without direct encounters with predators. If predators vary in their level of threat, discriminating between individual predators may be beneficial. Humans often vary in their response to wildlife: discriminating between dangerous and non-threatening people may allow individuals to avoid danger while exploiting anthropogenic resources. Corvids are abundant in urban and agricultural habitats, are persecuted as pests, and show remarkable discrimination and learning abilities during encounters with people. Here, we investigated whether wild jackdaws (*Corvus monedula*) use social cues to inform their response to unfamiliar humans. Jackdaws were presented with an unfamiliar person alongside playbacks of conspecific alarm calls or contact calls. Birds presented with alarm calls exhibited a stronger fear response in subsequent trials than birds presented with contact calls. This suggests that jackdaws use social cues to learn about individual predators that vary in their level of threat, and provides a mechanism by which information about dangerous people may be transmitted through populations in the wild.

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Large-billed crow fledglings learn a novel foraging technique from parents inside their natal territories

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An isolated population of large-billed crows (*Corvus macrorhynchos*) on Shickotan Island is characterized by several foraging traditions which have been persisting for at least the last five decades. We introduced into the population a novel foraging technique. As a result, we observed how it has been socially transmitted from parent crows to their youngsters while they were so young as to stay inside their natal territories.

The experiments were carried out during the large-billed crows' breeding period, when each crow's breeding pair occupies and protects their nesting territory. Three breeding pairs of crows have been taught to open (remove a lid) a red one of four boxes differing in color while their chicks were in the nests. The fledglings began to follow their parents through their natal territories as old as 60-65 days and from then they could observe what parent crows were doing at the experimental tables. At the age of 91-92 days old all the youngsters first flied up to the experimental tables without parents. They all removed the lids from the boxes on the first try. However, only one of them opened the red box. Like their parents they had learned to choose the correct box after 7-13 trials.

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Male trajectory as a reproductive strategy in the sexually cannibalistic spider *Nephila clavipes*

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Sexual cannibalism is the ultimate sexual conflict in a mating system. It is a rare phenomenon in nature, but common in some spider families. The fitness consequences for male spiders depends on when cannibalism occurs, with pre-copulatory cannibalism being the most costly since males would forfeit reproduction. Due to this sexual conflict, it is predicted that males have evolved traits to avoid pre-mating cannibalism and ensure reproductive success. A recent study showed that males settle near females in spatial hierarchies that appear to balance the benefits of proximity to the female with the costs of being so close as to risk death. Yet, this study only provides an end-point estimate of the behaviour that males show, and information on how males move, compete, and settle disputes is missing. We therefore lack a clear picture of how selection may have operated to shape this behavioural trait and how the interactions between males and females, as well as between males (e.g. with respect to prior residence effects), influence the success of reproductive strategies. Therefore, in this project I will employ machine-vision based automated tracking to quantitatively describe and compare males' trajectories as they approach a female and simultaneously use laser vibrometry to measure vibrations emitted by the female and male as a direct metric of social interaction. My study will provide a greater understanding of the interactions that occur between sexes in a dangerous and competitive mating system using *Nephila clavipes* spiders.

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Meaning, cost and convention: how signaling costs can shape the meaning of signals.

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Conventions determine the meanings of words in human language. Do conventional meanings exist in non-human communication? If so, game theoretical tools would give us a powerful tool to analyze meaning. Yet, early behavioral ecologists (e.g Zahavi & Maynard Smith) rejected the idea of conventionality in non-human communication because they argued that conflicts of interest nearly always exist between non-human signallers and receivers. It is difficult to fully understand this argument because these early behavioral ecologists had a fairly primitive understanding of conventions. We re-consider their argument using a modern definition of signalling conventions, and doing so we develop a more nuanced version of the Zahavi-Maynard Smith argument. We consider a situation with two possible signal systems, such as long tail means good or short tail means good. In the absence of conflicts of interest, both are stable equilibria of the signalling game; so the meaning of tail length is, by definition, conventional. We show that introducing conflicts of interest causes both signalling systems to destabilize, so we lose not only signalling conventions, but all signalling. Additionally, earlier investigators have famously shown that 'honesty' can persist in the presence of conflicts of interest when dishonest signallers pay marginally greater costs. We show that when two signalling equilibria are possible, any sufficiently large cost differential can stabilize signalling, but the direction of the cost difference determines which signalling system persists.

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Meta-analytic insights into state-dependent effects on risk taking behaviour

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Different behavioural responses expose individuals to differing levels of risk, particularly in contexts involving novelty and predation. Contrasting hypotheses suggest that the physical condition of individuals influences their readiness to take risks, based on the costs and benefits of risk-taking behaviours. For example, the asset protection principle proposes that higher condition animals have more to lose in terms of future reproductive potential, and thus, should be more risk averse. In contrast, the state-dependent safety hypothesis suggests that high condition individuals may be more likely to survive risky situations, so may be willing to make riskier choices. In this pre-registered study, we quantify the links between individual condition and risk-taking across species. First, we systematically review studies that manipulate individuals' nutritional-/energetic-state across ontogeny, and subsequently measure risk-taking behaviour across a range of experimental contexts (n = 5453 abstracts, 639 full-texts screened). We then use a phylogenetic meta-analyses to test whether the condition-risk relationship (1) is context-dependent (e.g. between contexts involving predation, novelty, risk-sensitive foraging etc.); (2) is sex-dependent; and/or (3) varies when the condition manipulation is applied in juvenile or adult life stages. This meta-analysis provides insights into the roles of state-dependency and developmental plasticity in driving behavioural variation.

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Navigation capacities of the kinkajou (*Potos flavus*)

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The emerging movement ecology paradigm proposes that navigation capacity is one of four fundamental properties that drive and define animal movement (Nathan et al., 2008). The primary goal of the research I will present at the ASAB 2019 summer conference is to determine whether and how kinkajous (*Potos flavus*) use memory to navigate efficiently between important feeding locations. The presence of high-use routes in kinkajou movement (Crofoot, unpublished data) suggests they may use episodic-like memory to anticipate the locations of fruiting trees and move directly to them. Because kinkajous are arboreal and frugivorous but minimally social, knowledge of their navigation capacities will help elucidate the roles of diet (Milton, 1981) and sociality (Reader & Laland, 2002) in the evolution of elaborated cognitive systems. I will travel to Barro Colorado Island, Panama from May through mid-August, equip six kinkajous with GPS collars, and set up an array of feeding stations within their home ranges. I will actively track and observe kinkajous for four-hour periods throughout the study. By identifying the impact on kinkajou movement and behavior of experimental changes in the availability of food at each station, I will test whether their use of routes can be sufficiently explained by alternative hypotheses: the structural constraints of the canopy, the ability to detect perceptual cues of food from long distances, and/or the establishment of scent-marked trails. At ASAB I will present initial findings from changes in movement characteristics over time and a multinomial logistic regression of feeding station choices.

Nature calls: does ecology explain abnormal behaviour and breeding problems in captive psittacines?

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Psittaciformes are popular pets and aviculture species. However, in captivity they show species variation in susceptibility to problems such as stereotypic behaviours and poor breeding. For example, feather-damaging behaviour (e.g., self-plucking) is prevalent in African grey parrots, *Psittacus erithacus*, but rare in Senegal parrots, *Poicephalus senegalus*; while monk parakeets, *Myiopsitta monachus*, breed readily, yet blue-throated macaws, *Ara glaucogularis*, do not. Comparing species using phylogenetic comparative methods can unpick fundamental bases of problems; thereby identifying species pre-disposed to be good pets and informing captive breeding management. We investigated relationships between species-typical biological traits proposed to influence welfare, and three welfare-sensitive captive outcomes: feather-damaging behaviour (FDB), other stereotypic behaviours (SB), and hatch rates (HR). Prevalences of FDB and SBs for 53 species (~1,380 birds) were gleaned by surveying pet parrot owners. Captive HRs (chicks hatched/breeding pair/p.a.) for 122 species came from Allen and Johnson (1990 Psittacine Captive Breeding Survey). Using phylogenetic generalised least squares regressions, we assessed effects of the following aspects of species-typical biology on welfare: sociality (maximum group size, communal roosting); foraging effort; ecological flexibility (diet and habitat breadth); intelligence (innovation rate, relative brain volume); and IUCN conservation status. Effortful foraging modes ($T_{3, 34}=-2.25$, $P=0.03$, $\lambda=0.88$) predicted FDB. Relatively large brain sizes predicted SBs (whole body: $T_{3, 36}=2.84$, $P=0.01$, $\lambda=0.29$; oral: $T_{3, 37}=3.62$, $P=<0.01$, $\lambda=0$). More threatened species had lower captive HR ($T_{5, 75}=-2.18$, $P=0.03$, $\lambda=0.39$). These traits can thus be considered species-level risk factors for poor parrot welfare, providing an evidence-based platform to inspire ways of tackling these problems.

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Population- and age-specific migration landscape of the European honey buzzard

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Birds of prey are morphologically adapted to energy-efficient soaring flight, which allows them to use upward moving air currents to gain height and consequently cover long distances while expending little energy. This leads to the trade-off of poor powered flight and causes a general avoidance of flying over water-bodies where updrafts are weak or absent. Adult European honey buzzards *Pernis apivorus* breeding in the Netherlands show this pattern very well on autumn migration to sub-Saharan Africa, as they circumvent the Mediterranean Sea by flying through the strait of Gibraltar. Juvenile and adult honey buzzards from Finland, however, show much more spatial flexibility on autumn migration and in crossing the Mediterranean Sea. Juveniles are especially more likely to undertake long flights over the Sea. We used GPS-tracking data to investigate the variations in migration ecology between the two populations (the Netherlands and Finland) and between the two age groups of the Finnish population. We analyzed the data at the intercontinental scale along the complete migration routes and at the regional scale over the Mediterranean Sea. We found that at the large scale, the response of each group to wind conditions shapes its migration landscape. At the small scale, juveniles benefit from stronger updraft over the sea due to later migration onset than adults, hence their ability to perform longer water-crossing. This study demonstrates the importance of remote-tracking data sharing in advancing our understanding of intraspecific differences in migration ecology and behavior.

Predation as a personality trait in a wild fish population

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Consistent behavioural differences between individuals (i.e. personality variation) can influence a range of ecological and evolutionary processes. Variation between individual predators in commonly measured animal personality traits, such as boldness and activity, has previously been linked to the risk these individuals pose to prey. By studying wild piscivorous fish (pike cichlids, *Crenicichla frenata*) in their natural environment using experimental presentations of prey and control stimuli, we present the first evidence for a 'predator personality trait' that is independent of the correlation between predator boldness (and/or neophobia) and encounter rates with prey. Individual predators differed consistently in the amount of time spent near a stimulus prey shoal, but there was no evidence of consistent differences between individual predators in the control (the same apparatus lacking prey). Crucially, variation in the response to prey could not be explained by the response of the same individuals towards the control, suggesting that the differences between individuals in responding to prey could not be attributed to individual traits or environmental factors that determine encounter rates. By revealing a novel trait which differs consistently between individual predators, these results suggest that the risk posed by individual predators cannot be adequately predicted from typical axes of personality variation, and highlights the importance of inter-individual variation in traits with direct ecological relevance.

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Prospecting behaviour in wild jackdaws

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Prospecting behaviour serves as a tool for gathering information about potential future breeding sites for the prospector. It has been observed in not only jackdaws but other birds such as black-legged kittiwakes, cormorants and house sparrows. When prospecting, birds are looking for cues and public information such as the provisioning rate by the parents, egg number in a nest or parasite load. Birds use this information to decide on a higher quality breeding site which can be crucial to their success. It is thought that younger birds and failed breeders are more likely to exhibit this behaviour as they stand to gain more by using their time to prospect. However, little is known about prospecting in wild birds. Interestingly, jackdaws have been seen to prospect not only before and during the breeding season, but immediately after it as well. With this in mind, I hope to answer three main questions with my masters by research project. Firstly, why are jackdaws prospecting immediately after the breeding season? Secondly, who is exhibiting this behaviour? Is it an age/ sex biased trait? And thirdly, what do these individuals stand to gain? To answer these questions, I am working with the Cornish Jackdaw Project, which has been running since 2013. Over 2100 birds have been ringed with unique colour ring combinations. Each combination includes an RFID (radio frequency identification) tag which will allow identification of individual birds at each of the 80 nest boxes used by the project.

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Proteomic stress responses vary with personality in the beadlet sea anemone (*Actinia equina*)

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Within species, a key determinant of the ability to cope with anthropogenic environmental change is the magnitude of phenotypic variation within a population. An important aspect of this is repeatable behavioural differences among individuals, termed personality. However, few studies have investigated the molecular mechanisms underpinning personality variation and how these could relate to differing individual responses to environmental perturbation. Intertidal species are particularly vulnerable to climatic shifts as they already spend much of their time living close to their environmental limits. Here, we aimed to assess variation in the proteomes of bold and shy beadlet anemones under different stressors. We allocated anemones of each personality type to four treatments, exposing individuals to an acute stimulus, chronic high temperatures, both, or no stressors, and assessed their proteomic expression. In the 'no-stressor' treatment, PCA analysis showed clear differences between the proteomes of personality types. After an acute stimulus, shy individuals up-regulated proteins involved in mediating stress responses more than bold individuals. Under chronic temperature stress, bolder individuals exhibited a clearer change than their shy counterparts, up-regulating structural proteins, likely to mitigate for the loss of structural integrity experienced at thermal extremes. Our research suggests that personality is intrinsically linked to proteomic expression in this species. It further indicates that different personality types may be subject to trade-offs in their susceptibility to different types of stress. Regular exposure to high temperatures, of the type which might be brought about by climate change, may impose greater selective pressure on some personality types than others.

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Pushing the switch: lionfish show adaptive foraging behaviour under multiple resources scenarios

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Biodiversity is declining on a global scale, and the spread of invasive alien species (IAS) is one major driver. Effective means of assessing the consequences of IAS on native prey population stability remains a vital goal to invasion ecology. Here we use two classic ecological concepts, functional responses and prey switching, to assess the impacts of the Red lionfish (*Pterois volitans*), a notorious invader that has spread over the Western Atlantic and Caribbean, and most recently the Mediterranean Sea. For three prey species (*Palaemon varians*, *Gammarus oceanicus* and *Artemia salina*), when present individually, destabilising Type II functional response (FR) curves were found, owing to high resource acquisition at low densities. Maximum feeding rates were highest towards *A. salina*, whilst *P. varians* and *G. oceanicus* were more similar. However, when multiple prey types were presented simultaneously, the proportion of specific prey items consumed was reliant on the proportion available in the environment, indicative of prey switching behaviour by lionfish. Giving the central role of switching in stabilising predator-prey dynamics, the displayed switching propensity by lionfish may remediate their in-field impacts, by offering low density prey refuge in biodiverse communities via frequency-dependent predation. In turn, this may drive stabilising Type III FRs empirically upon prey, in contrast to consumptive traits exhibited in single-prey systems. We thus highlight opportunities to further impact prediction in invasion science using FRs and prey switching and argue for the explicit incorporation of such methodologies into the assessment and prediction of established, emerging and future invasive alien species.

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Quantifying echo detection rates in the sonar cocktail party nightmare

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Active sensing animals detect their surroundings by emitting probes of energy and analysing how the environment has altered the probe's spectrotemporal characteristics. However, active sensing animals like echolocating bats can be 'jammed' by the probes of conspecifics. Echolocating bats detect their surroundings by emitting loud ultrasonic calls and listening for the returning echoes that are reflected off objects around them. In the presence of loud sounds, such as the calls of other bats, they are unable to detect their own echoes. This is known as the cocktail party nightmare. Despite this problem, many bats fly and echolocate in groups and roost socially.

We present for the first time a biologically driven theoretical framework to estimate the sensory detriment a bat may experience in the cocktail party nightmare. By incorporating known psychoacoustic and acoustic phenomena of bat echolocation, we quantify the echo detection rate in the presence of loud conspecific calls. We show that a bat detects the majority of echoes within two emitted calls, all echoes once within six emitted calls, and all echoes twice within eight emitted calls. These results indicate that bats obtain frequent but partial 'glimpses' of their surroundings even under apparently difficult sensory conditions. Our results show that the sonar cocktail party may be more of a 'challenge' than a nightmare.

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Quantifying the acoustic parameters of overlapping echolocation calls in free-flying horseshoe bat aggregations

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Many animals are social, often moving, interacting and vocalizing in dense aggregations. Understanding their behavior and vocalizations pose a challenge, particularly if recorded calls overlap in time and frequency. Like many echolocating bats, horseshoe bats fly and echolocate in dense groups. They emit calls at high duty cycle and with a constant frequency (CF) part sandwiched between frequency-modulated (FM) parts. This call type poses a particular challenge for systematically analyzing multi-bat situations, as call recordings suffer from spectrotemporal overlap and Doppler shifts. Our study fills the gap in understanding how horseshoe bats vary their echolocation call parameters when flying alone and together with conspecific or heterospecific bats. We predict that bats will alter their call parameters in multi-bat contexts by increasing CF and FM bandwidths to avoid spectral overlap. We recorded synchronized video and audio data of horseshoe bats flying in a natural cave habitat, and developed a method to quantify their call parameters in single-bat and multi-bat situations. We first obtained independent estimates of the number of simultaneously flying bats based on the video data, peaks in the call spectra, and visual screening of call spectrograms. We then automatically analyzed the call recordings in regular time intervals matched to the bat counts to quantify average call parameters such as CF peak frequencies, CF and FM bandwidths and terminal frequencies. Our study presents a novel approach for studying echolocation in groups of CF bats.

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Response towards heterospecific non-alarm signals in social passerines

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Animals with overlapping habitats are more likely to have common predators and a multitude of studies spanning different model organisms have shown eavesdropping of alarm signals among heterospecifics. This is unsurprising as alarm calls provide direct information about the presence of a predator and recognition of these calls from conspecifics and heterospecific may be under strong selection. However, not many studies have looked at the extent of eavesdropping on non-alarm signals, especially in closely related sympatric species. We examined interspecies communication using contact call (a type of call use to communicate between group member over long distance) between two sympatric congeneric social passerines, Jungle Babblers (*Turdoides striata*) and Large Grey Babbler (*Turdoides malcolmi*). We exposed wild population of both species with three playback stimuli; congeneric sympatric species as experimental stimulus, conspecific call as positive control and call of sympatric non-congeneric species as negative control. Our results show that significant response is shown by both species towards experimental stimuli as well as to conspecific calls. On the other hand no response is shown towards the call of non-congeneric species. We also demonstrate that the nature of response towards conspecific call and to that of the heterospecific is dissimilar. From this study we show that there is heterospecific signal recognition of non-alarm signal between two congeneric babbler species which could, through future studies, provide interesting insights into the information content of signals and also on the evolution of signalling systems in these social birds.

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Responses of nesting Arctic terns (*Sterna paradisaea*) to disturbance by human

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Nesting birds often respond to human disturbance as to a predatory act. In the case of the high Arctic, the disturbance of incubating birds may be fatal if they do not return to the nest in time. In addition, it is assumed that birds in the high Arctic are not shy and do not respond to human presence fearfully. We tested how quickly the Arctic terns nesting in two colonies in Svalbard return to the nest after human disturbance. One colony was situated inside a town where the terns were regularly harassed by human presence. The second colony was on a glacial foreland where breeding terns have limited experience with humans. We found that terns without frequent experience with humans returned to the nest about five minutes after disturbance, while urban terns habituated to the human presence returned within a few tens of seconds. The urban terns in this way likely solve the risk of spending too much time off the nest, which could lead under the conditions of the high Arctic to stopping embryogenesis. Terns from a remote colony do not show lower hatching success of their eggs than the urban ones, however, incubation and the whole population of terns could be threatened when there is more frequent disturbance by researchers or tourists.

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Seasonal adjustment of heart rate and body core temperature in free-living greylag geese

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Animals adaptively regulate their metabolic rate and hence energy expenditure over the annual cycle to cope with energetic challenges. We studied energy management in greylag geese. We describe profound seasonal changes of heart rate (fH) and body temperature (Tb), with distinct peaks in summer and troughs during winter. Next to seasonal variation, we also found significant daily modulation of fH and Tb. Daily means of Tb together with those of air temperature and day length were the most important predictors of daily mean fH, which was further modulated by precipitation, reproductive state, and, to a minor degree, social rank. Peaks of fH and Tb occurred earlier in incubating females compared to males. Leading goslings increased daily mean fH. Our results suggest that in greylag geese, pronounced changes of fH over the year are caused by photoperiod-induced changes of endogenous heat production. Similar to large non-hibernating mammals, tolerance of lower Tb during winter seems the major factor permitting this. On top of these major seasonal changes, fH and Tb are elevated in incubating females.

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Sex Pheromone Makes Sense (in Moth)

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Sex pheromone have primarily evolve for the sake of reproduction, thus a high specificity is required to avoid mating with a wrong species.

Typically, sex pheromones are specific blend of a few components, but difference in both the combination and their ratio of the pheromone components provides a range of possible species specific pheromones. The cost of mating with the wrong species is expected to promote a direct selection to reduce sex pheromone's variation among females within a species. Nevertheless, an existing variation was found in the ratio of the pheromone components in moth species that had been tested.

This research aimed at testing whether sex pheromone blends provide information regarding the female's quality. We used the pink bollworm (*Pectinophora gossypiella*) as our animal model. From the laboratory colony, we selected females representing different phenotypic conditions as size and age. We removed the female glands at calling time and analyzed the pheromone amount and ratio. We found significant differences in the pheromone ratio of components but not in their amounts. We than tested if male moths can distinguish between females' quality through their pheromone characteristics. In a wind tunnel assay we introduced each male to two groups of females that differ in their phenotypic conditions and recorded their choice of mate. Indeed, males showed a significant preference for females in better conditions. These findings strongly suggest that female sex pheromones provide information regarding the quality of the female as a mate.

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Size as the Attributes Used by Birds for Predator Recognition

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It has been repeatedly proven that birds use simple morphological characteristics of raptors for predator recognition. These traits include the curved beak, hooked claws and supraorbital ridges common to all birds of prey or an undulated belly and yellow eyes typical for most members of the genus Accipiter. However, those so-called sign stimuli never occur in isolation. Another characteristic that may affect predator recognition is body size, which can be a determining factor in the size of the preferred prey. During winter feeder experiment, we tested the effect of the body size and overall coloration of dummies mimicking a Eurasian sparrowhawk (*Accipiter nisus*) on its recognition as a threat by songbirds. All dummies were provided with typical raptors sign stimuli (curved beak, talons) as well as with one specific characteristic of the genus Accipiter (yellow eyes). Two dummy sizes (a real-life size of a sparrowhawk and a size reduced to that of a great tit) and four types of coloration (sparrowhawk/pigeon/European robin/great tit) were used for the experiment. A dummy mimicking a pigeon (normal pigeon size) was used as a control.

Birds approaching the feeder were less afraid of all downsized dummies than of any dummy in the size of a sparrowhawk, including the control pigeon dummy. They did not perceive them as a threat, regardless of any potential sign stimuli. Of the dummies in the size of a sparrowhawk but with modified coloration, only the dummy with the coloration of the European robin (a small songbird, only rarely present at the feeder) caused greater fear than the control pigeon dummy. The effect of coloration we observed is concordant with previous cage experiments. However, the effect of the size is quite different. In the cage experiment, tits reacted to the downsized and life-sized dummies in the same way. The most likely reason lies in the different size perception in a cage and feeder experiments.

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Stereotypic pacing and faecal corticosterone metabolites as non-invasive indicators of stress in rehabilitating green turtles (*Chelonia mydas*)

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Species of marine turtles are experiencing large population declines, and there are many conservation projects worldwide which aim to rehabilitate and release sick or injured turtles. Whilst in captivity, turtles will inevitably experience unnatural conditions and large amounts of human interaction, both of which may cause stress to the animal. Green turtles (*Chelonia mydas*) are believed to travel 5-10km per day, and animals with a similarly large range area have been shown to develop stereotypic behaviours such as pacing whilst held in a captive environment. However, there is both limited research of stress in marine turtles, and a lack of subjective method to quantify the locomotion of pacing. Here we trialled a new method of incorporating transition probability to identify repeated pathways. The results of which were correlated against a biological marker of stress in the form of faecal corticosterone metabolites (FCM), as a non-invasive alternative to the classical use of blood sampling which can itself induce stress.

The aim of the study is to develop our ability to identify stress in real-time and non-invasively, in order to improve recognition and influence best practice for the welfare of captive marine turtles. This may reduce any chronic effects of stress such as immunosuppression, inappetence and impaired reproductive function, which could subsequently support the success of rehabilitation efforts and other conservation interventions. It is hoped the successful application of the methods will advocate their use within future research and captive care of green turtles.

Stereotypy found in budgerigar song using ideas from linguistics and human speech

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Studying the communication systems of non-human animals is difficult because we are missing knowledge about both meaning (top-down approach) and fundamental units (bottom-up approach). Most efforts to study the units comprising non-human animal vocalizations have focused on elements of sound separated by silence. This has been successful in some species, where elements separated by silence are easily identifiable because of their stereotyped nature. However, in other species' song, such as budgerigar warble, elements rarely repeat. Budgerigar warble contains long units separated by silence that have low degrees of stereotypy. This has parallels to human speech where often multi-word utterances are produced without any intervening silences, and many of these utterances never repeat. Instead of silence, rapid changes in the signal structure indicate that a unit type has changed (e.g., transition from 'p' to 'o'). Here we show that breaking up an acoustic signal based on rapid transitions may be useful in identifying basic units in vocal communication in budgerigars as well. This discovery has led us to observe other structural parallels to human vocalizations. These findings suggest that budgerigars may be an ideal model species for human language because we can begin to tease apart what aspects of human language are cultural phenomena and what aspects are the result of widely-shared sound production biases. In addition, by using what we know about the species that has been most studied in terms of vocal behavior, namely the human, we can potentially crack the code of unstereotyped non-human vocalizations.

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The ability of breeding titmice to recognize a predator and nest parasite.

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The common cuckoo (*Cuculus canorus*) is a common nest parasite of small passerines. Its visual appearance importantly resembles the Eurasian sparrowhawk (*Accipiter nisus*), and it is supposed that this similarity protects cuckoo from attacks of adult host birds. Previous studies showed that titmice (namely Great tit - Parus major), which are usually not parasitized by cuckoo as they breed in tree hollow, commonly attack cuckoos when encountered. We decided to test the theory that titmice mistake the cuckoo for the sparrowhawk and therefore try to chase it away. We presented stuffed dummies of cuckoo and sparrowhawk at the nest boxes, where titmice (great and blue tits - *Cyanistes caeruleus*) are laying their eggs. As a control we presented also the dummy of great woodpecker (*Dendrocopos major*) a common nest predator preying on eggs and chicks of titmice, rufous form of cuckoo, which does not resemble sparrowhawk, but represents equal danger as the grey form and a harmless feral pigeon (*Columba livia. f. domestica*). We showed that responses of titmice to sparrowhawk and cuckoo importantly differ. Titmice usually approached the sparrowhawk and mobbed it. On the contrary, titmice were further than 10 meters from the nest, when there was a dummy of cuckoo (both forms) as well as woodpecker, which correspond to low interest in the dummy. We can conclude that titmice are able to recognize cuckoo from sparrowhawk and the birds that decide to attack the cuckoo do this intentionally.

An agent-based model to simulate the formation of self-assembled structures in army ants

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Army ants of the genus *Eciton* join their bodies together to create self-assembled structures that are responsive to traffic and environmental conditions, and function as a kind of living infrastructure for the colony. Here I present an individual-based model that simulates the formation and growth of two kinds of structures, bridges and flanges. These two structure types form under different conditions in nature, and the model reproduces both cases, as the same underlying set of individual-level rules results in different structures depending on the geometry of the environment. In the model, ants interact with the environment by detecting the surface ahead (either a void, solid surface, or an ant structure), and the concentration of pheromone deposited by other ants. Mobile ants interact with others encountered within a sensory zone representing the antennae and legs, and ants within a structure can sense contacts from other ants passing over the structure. The model takes three inputs corresponding to variables measured from experimental data: the overall rate of traffic flow; the proportion of ants carrying prey; and the proportion of bidirectional traffic. With these inputs, I test the model under different environmental conditions corresponding to two different experimental setups, for bridges and flanges. Within certain ranges of behavioral parameter values, structures of similar size, geometry, and growth dynamics emerge for both bridges and flanges when compared to experimental data given the same traffic conditions, and I show which parameters appear to be important for the formation of stable and responsive structures.

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The role of memory in foraging efficiency under uncertainty: ant trajectories and beyond

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Exploring how animals orchestrate their (individual or collective) foraging excursions in time and space when facing unknown environments represents a way to test their cognitive capacities under uncertainty. However, the corresponding (trajectory, space-use, etc) dynamics can be often complex to analyze and understand. In this contribution we will present some results obtained by (i) tracking ant (*Aphaenogaster senilis*) trajectories in arenas with different topological properties, so involving different levels of organization, and (ii) using methods and ideas borrowed from statistical physics to analyze the patterns observed. In particular, we want to understand how individual and/or collective 'memory' could be a driving force for the generation of these patterns. Moreover, we will discuss these results in connection to other experiments we are carrying out in which we study the navigation and exploration abilities of higher organisms (e.g. humans). As a whole, we will try to show that a combination of multispecies experiments and a mechanistic (random-walk) treatment could represent a promising approach to understand the role that cognitive memory/prospection play in animal response under these and similar scenarios.

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Think before you speak! Using thermal imaging for detecting intention and preparation to vocalize.

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Acoustic signals play a role in numerous aspects of animals' lives and are extensively studied across multiple taxa on structural, combinatorial and functional levels. However the signal production phase is the terminal stage of a signaling event. Preceding the audible vocalization, there is stimulus processing, decision making and preparation for sound production. These often non-detectable stages are integral to the dynamics of signaling, as any of them might result in a vocalization not being produced. Monitoring the stages preceding vocal production will allow us to answer questions related to signal planning and the dynamics of signaling motivation.

One way to assess the intention to vocalize is by looking at the preparation of articulators. In human conversations the next speaker identity is predicted by changes in breathing, with participants motivated to speak next taking deeper breaths. Additionally deeper inhales were associated with longer sub-sequential speaking, indicating an early planning of a conversational turn.

We examine if similar phenomena exist in vocal interactions of wild meerkats (*Suricata suricatta*). For working with free ranging animals we are developing a noninvasive procedure, using thermal imaging for breathing depth and rate detection, as expiration and inspiration are associated with surface temperature changes in the animals' nasal region. Synchronization of breathing curves with audio recordings can expose stereotypic breathing patterns, preceding vocalization events. Detection of preparation for calling might indicate to what extent animals plan the timing and duration of their vocal bouts and potentially show if external stimuli can negatively affect calling motivation, suppressing the planned vocalization.

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Using deep learning to study collective behavior

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Deep learning is a powerful way to learn from data. We have used it to develope a tracking system for up to 100 animals and to model behaviour. For behaviour, we have found that modular deep nets allow for both a high predictive power and for insight. I will also discuss applications for behavioural classification and for finding interaction rules consistent with collective patterns using inverse Reinforcement Learning.

Vocal mimicry in budgerigars does not depend on octave equivalence

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The behaviour of vocal mimicry - copying of allospecific vocalizations or sounds from the environment - is rare among animals, and its preconditions remain unclear. In this study we hypothesized that vocal mimicry may be supported by perception of octave equivalence. Octave equivalence is the perceived similarity of notes separated by an octave, that is, a doubling in frequency. Humans use octave equivalence perception in vocal learning as it enables young children to approximate adult vocalizations where the pitch lies outside their vocal range. Specifically, children shift the fundamental frequency of the adult vocalization upwards by an octave when reproducing it. This behaviour is rooted in physics: The octave is also the first harmonic of any tonal sound including the human voice. We hypothesized that non-human animals may use octave equivalence in a similar way when vocally mimicking sounds outside their vocal range. In this study, we tested whether a vocal mimicking species, the budgerigar (*Melopsittacus undulatus*), perceives octave equivalence. Budgerigars were trained on and tested for octave equivalence in a go/no-go operant task. In contrast to humans tested using the same paradigm, budgerigars showed no evidence of octave equivalence perception. This result suggests that vocal mimicry does not necessarily depend on perception of octave equivalence. However, the responses of the budgerigars were highly similar to those of black-capped chickadees in a previous study using the same paradigm. This suggests that there may be a common tone grouping mechanism among avian species that is different than that of humans.

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Weaver ant-inspired rules for self-assembly and swarm robotics

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Weaver ants (*Oecophylla smaragdina*) dominate their ecosystem by combining the best aspects of small individual size with coordinated collective power. They are one of only a few ant genera that can join their bodies together to create self-assemblages that perform vital functions for the colony. These structures include rope ladders that extend their reach, bridges that act as highways for ant traffic, and pulling chains to roll leaves together for nests. Ant self-assemblages are formed using simple agents and interaction rules, yet the emergent structures are sophisticated, forming when and where required, adapting to environmental conditions, and self-repairing when damaged. Our project induces colonies to self-assemble pulling chains, bridges and hanging chains in the laboratory, performing detailed behavioural analyses to work out the simple rules used by individuals to decide when and where to join or leave a structure. Individuals will be uniquely marked and tracked using state-of-the-art technology to provide the first comprehensive quantification of behaviours during self-assembly, allowing us to statistically link individual-level behaviours to group-level functional outcomes. These data will be combined into a computer modelling framework that will demonstrate how to build things that build themselves. This knowledge may be applied to many other complex systems, from manufacturing to health, where benefits could include efficiently manufacturing nanomaterials or predicting tumour formation. This project will directly demonstrate a swarm robotics application, producing control algorithms that allow robot swarms to emulate ants, self-assembling into useful structures that greatly enhance their capabilities, especially in unknown or dangerous environments.

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Stress resilience, methylation, and the dynamic regulation of glucocorticoids

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There is often remarkable variation in how individuals cope behaviorally with similar challenges. Although this variation can have fitness consequences, the mechanisms that generate it remain poorly understood. Recent findings from research in a large population of free-living tree swallows (*Tachycineta bicolor*) has identified global patterns of DNA methylation as a predictor of the behavioral response to stressors. At the same time, work is showing that the response to challenges is influenced by individual variation in the regulation of glucocorticoid hormones. Birds that both mount a strong glucocorticoid stress response and are able to rapidly and effectively terminate that response through negative feedback cope better with stressors. Experimental work has also found that exposure to a few brief, acute increases in glucocorticoids can have long-term impacts on parental behavior and offspring phenotype in free-living birds. These and other experiments are providing insights into how physiological differences, in combination with experiences, can shape future behavior and fitness.

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Active smelling in the American cockroach, *Periplaneta americana*

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Olfaction has traditionally been studied as a slow and static sense, even though it is clear that animals actively enhance odour perception with specific behaviour (sniffing, flight manoeuvres, antennal movements, etc.). We use the American cockroach (*Periplaneta americana*), which actively oscillates its long and highly mobile antennae during search, to study active olfactory sensing strategies. We hypothesize that the animals adapt their movements to changing characteristics of a complex olfactory environment in order to extract relevant information and make decisions. Using behavioural wind-tunnel experiments that include antennae and body tracking and odour-plume manipulations, we study the relationship between odour encounter, movement decisions and plume structure. Our first results show that both odour onset and offset affect antennal movement patterns in an odour-specific manner and that these movements are used in locating an odour in space. We are further investigating how antennal movements affect the plume structure and reception of the odour.

Collective Inversion of Individual Preferences in cockroaches

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Decision making is modulated by both environmental and social cues. For example, when choosing shelters, cockroaches respond to both food and social odors. We study the interactions between these components in the American cockroach, *Periplaneta americana*. Individually, cockroaches show attraction for a vanillin odor. However, in groups they display a change in preference; aggregating at a control rather than a potential food odor site. The aim of the study was to investigate this further and elucidate mechanisms underlying this change in preference. Specifically, we tested how much the social shift is mediated by olfaction by testing individuals in the presence of both food and social odors. When presented independently, both vanillin and a feces extract odor are attractive for isolated individuals. However, when these same odors are presented simultaneously, isolated cockroaches show no preference for the mixture over a control. Our results show that individual preference to vanillin changes in a group context, including conditions in which an odor is the only signal for group presence. In order to reveal whether perception of the two attractive odors concurrently induce modulation at the olfactory centers, we monitored brain activity of cockroaches exposed to different concentrations of vanillin, feces extract and a mixture of the two odors. By monitoring calcium levels in the in the antennal lobe, our preliminary results suggest modification in sensory perception already at the primary olfactory center. We observe a partial overlap in response patterns for both odors with a reduced response to vanillin when applied simultaneously with feces extract. Further experiments are planned to test whether the behavioral change is the result of competition avoidance and outline its neural basis.

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Decision-making efficiency in wild great tits, with real world consequences

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In animals that provide care for their young, choosing the right offspring to feed is a crucial decision, and the speed at which parents make that decision can substantially impact fitness. Signalling theory suggests that offspring signals for food may have evolved because signals increase parental decision-making efficiency—essentially, the less time parents spend choosing whom to feed, the more time parents have to gather food. However, whether offspring signals really do boost the efficiency of parental decision-making is still untested. Furthermore, while neuroscience laboratory studies have identified many factors that influence decision-making speed, these studies typically take place under very controlled conditions that may not be reflective of animals' evolutionary context. We therefore conducted a study on wild great tits, *Parus major*, where we experimentally manipulated ecological conditions as well as the stimuli information provided to parents from offspring. We then measured how long it took parents to decide which offspring to feed under naturalistic conditions. We found that ecological conditions, the information provided by offspring, the final choice of offspring, and parent sex influence decision-making efficiency. In contrast to expectations from lab studies, we did not find an effect of stimuli noisiness. Our results suggest that efficiency in parent-offspring communication may be more strongly affected by the individual and ecological context than by the actual signals. More generally, our study highlights the importance of expanding the field of animal cognition from the lab to the field.

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Generalized rule learning and social tool use in cleaner fish

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Generalised rule application promotes flexible behaviour by allowing individuals to quickly adjust to environmental changes through generalization of previous learning. Here, we show that bluestreak ‘cleaner’ fish (*Labroides dimidiatus*) use generalized rule application in their use of predators, which act as social tools, in order to evade punishing fish clients. Such punishment occurs as cleaners do not only remove ectoparasites from client fishes, but prefer to feed directly on client mucus, which constitutes cheating and often results in aggressive chasing from the cheated client. We tested for generalized rule application in a series of experiments. First, we trained cleaners to approach one of two fish models in order to evade punishment (i.e. chasing) from a ‘cheated’ client model. Cleaners learned this task only if the safe haven was a predator model. During consecutive exposure to pairs of novel species, including exotic models, cleaners demonstrated generalization of the ‘predators-are-safe-havens’ rule by rapidly satisfying learning criterion in significantly fewer number of trials. However, cleaners were not able to generalize a ‘one-of-two-stimuli-presents-a-safe-haven’ rule, as they failed to solve the task when confronted with either two harmless fish models or two predator models. Our results emphasize the importance of ecologically relevant experiments to uncover complex cognitive processes in non-human animals, like generalized rule learning in the context of social tool use in fishes.

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Sharing the burden: on the division of parental care and vocalizations during incubation

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In species with biparental care, individuals only have to pay the costs for their own parental investment, whereas the contribution of their partner comes for free. Each parent hence benefits if its partner works harder, creating an evolutionary conflict of interest. How parents resolve this conflict and how they achieve the optimal division of parental tasks often remains elusive. In this study, we investigated whether lesser black-backed gulls (*Larus fuscus*) divide parental care during incubation equally and whether this correlates with the extent of vocalizations between pair-members during incubation. We then investigated whether pairs showing more evenly distributed incubation behavior had a higher reproductive success. To this end, we recorded incubation behavior and vocalizations for 24-h time periods. Subsequently, we experimentally increased or decreased brood sizes in order to manipulate parental effort, and followed offspring development from hatching till fledging. Although incubation bouts were, on average, slightly longer in females, patterns varied strongly between pairs, ranging from primarily female incubation over equal sex contributions to male-biased incubation. Pairs contributing more equally to incubation vocalized more during nest relief and had a higher reproductive output when brood sizes were experimentally increased. Thus, vocalizations and a more equal division of parental care during incubation may facilitate higher levels of care during the nestling period, as suggested by a greater reproductive success when facing high brood demand, or they indicate pair quality.

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Effect of Personality on the Response of Great Tits (*Parus Major*)

to Social Perturbation

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Achieving stability in a social group despite demographic variation enables individuals to better benefit from sociality. Social network theory highlights the importance of the role and position of individuals in ensuring robustness and resilience of animal social networks. Previous work has also demonstrated that individual-level traits can articulate the structure of the network. However the relationship between such traits and the ability of individuals to cope with perturbations at the network level remains to be explored. Here, we investigated the correlation between exploratory personality and individual reaction to changes in group composition in captive populations of great tits (*Parus major*). We found that birds facing such perturbations exhibited the same trends as described in previous studies. The birds increased their connectedness just after the perturbation, what seemed to hamper the pruning and structuration of the network over longer time period. Further, the consistent correlation between personality and social phenotype was disrupted by the perturbation. Although differences in the response to social disturbance were not significant, bold birds seemed to react quicker and to be less resilient than shy birds. The observed tendencies open intriguing avenues in understanding the mechanisms of social resilience and how individual variation may mediate group-level processes.

A new technique to measure anticipatory behavior and future applications

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Anticipatory behavior describes the actions taken to prepare for an upcoming event. In this study we tested the anticipatory behavior to distinguish different levels of interest inside the same event. We measured the intensity of anticipatory behaviors with two different techniques. We started by studied the dolphins' (*Tursiops truncatus*) interest for twenty game objects, then we took the objects with the highest level of interest (HLI) and those with the lowest level (LLI). In this way the event: interaction with objects, has been divided in two levels of interest according to which objects we gave to the dolphins. We trained dolphins to associate the arrive of different objects with different visual signal, then, for the first technique we measured how much time each dolphin showed anticipatory behaviors during the five minutes from the beginning of the signal to the arrive of the objects. For the second technique we analyzed the spatial behaviors in the same sessions use for the first technique and we measured the dolphins' distance from the starting point (the point of the pool where the objects were introduced into the water). Analyzing this data, using a general linear model, we found that, for all two techniques, anticipatory behavior was higher before the arrive of objects with HLI's than those with LLI. This means that all two techniques are able to study the anticipatory behavior and can be used to discriminate different levels of interest inside the event.

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Effect of competitive environment on female scent marking in house mice

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Competition for resources is a key driver of animal behaviour. Since direct aggression can be costly, signals of competitive ability may be used to minimise the need for escalated conflict. Among mammals, competitive ability is often signalled via scent marking to mark a territory and through the deposition of expensive scent mark components that can indicate an individual's condition. For example, house mice (*Mus musculus domesticus*) deposit expensive urinary proteins when scent marking their territory which can indicate condition and also increase signal strength and longevity of male territorial scent marks. Although most studies of competitive scent marking to date have focused on males, females also invest in competitive signalling, and investing in proteins may come as a trade-off particularly in relation to resources needed for successful reproduction. Here, we employ an experimental approach under controlled naturalistic conditions to test if female house mice adjust their investment in the production of urinary proteins used for scent marking, according to social conditions. For subjects established in breeding kin groups, we compare investment in urinary protein production and scent marking behaviours in the presence or absence of rival groups living in neighbouring territories. We would expect females that are exposed to rival groups to invest more in urinary proteins than those without rival groups to help reduce the likelihood of rival intrusions. Preliminary results of this long-term study will be presented.

Get back to home: Homing behavior in the rubí poison frog *Andinobates bombetes*

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Homing is the behavior exhibited by individuals of diverse animal species when they return to their territory after having displaced to areas far from it. In anurans, little is known about homing in Neotropical species whose reproduction consists in terrestrial oviposition and the individuals call from territories dispersed in the habitat. The rubí poison frog *Andinobates bombetes* is a diurnal and territorial species, whose reproduction is not associated to large bodies of water. In a forest remnant located in the department of Quindío, Central Andes of Colombia, we performed translocation experiments of individuals at distances between 5 and 90 m outside their territory. Of 105 displaced individuals, 31 returned to their territory. The probability that an individual exhibit homing was negatively related with distance, but was not related with body size and sex. Similar results have been reported in other poison frog species. Apparently, homing is widely distributed in the family Dendrobatidae, being *Andinobates* the fourth genus of this family where this behavior has been corroborated experimentally.

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Homing and parental care in the glassfrog *Centrolene savagei*: fathers come back more than singles

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Homing, the behavior of returning to a specific place (e.g. territory) after moving or being displaced out from it, is present in diverse species of invertebrates and vertebrates. In anurans, homing has been studied in species whose individuals have terrestrial habits, but little is known about such behavior in arboreal species; additionally, the relationship between homing and parental care have been poorly studied in vertebrates. Obtaining empirical evidence about homing behavior in arboreal anurans species, and mainly about the relationship between homing and parental care it is an important approach for understanding the evolutionary behavioral ecology of vertebrates. The glassfrog *Centrolene savagei* offers us a great opportunity to explore homing behavior in arboreal species and its relationship with parental care. In this species, adult males exhibit high fidelity to the calling place, and eggs clutches are laid by females in the upper surface of leaves overhanging streams. The care of such egg clutches is performed by males (fathers) and consists in brooding behavior and defense against predators. Between October 2017 and – October 2018, we realized 32 field trips, one-two nights each one, to a population in the Central Andes of Colombia. Along a transect of 420 m in a stream, we translocated 23 males (16 caring eggs, 7 singles) at distances between 5–80 m from their calling or breeding place to test whether the former males tends to exhibit more homing than the latter males. We also, registered the distribution pattern of males and egg clutches along the stream, and compared the mortality of embryos in egg clutches with and without a male caring them. Seven of the males caring egg clutches and one single male exhibits homing. Results of a binary logistic regression analysis indicate that homing probability is significantly higher in males caring eggs (i.e. fathers) than in single males. The distribution pattern of males and egg clutches is clustered, which, points out that adequate places for attracting females and breeding are located in specific places on the stream. Mortality was lower in egg clutches with parental care than in egg clutches without it. Altogether, our results suggest that homing in males of *C. savagei* is a behavior that offers adaptive benefits to them. By one side, single males could recover a calling place that is important to attract mates; on the other side, males with egg clutches return and reassume a parental care behavior which increase offspring survival chances.

A forked relationship - understanding the acoustic communication strategies in sympatric drongos

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The primary function of acoustic signals is to communicate information over optimal distances to their intended receiver, for various contexts. This is subjected to changes and distortions imposed by the physical structure of the habitat, as well as masking interference from co-occurring signals of other vocal species, especially from congeners. Passerine birds in particular, owing to vocal learning and mimicry, are highly vocally plastic, and have been relatively little studied in this regard. However, they pose interesting possibilities because of this, as this plasticity expands the range of possible behavioural and physics-based strategies they may employ to "get the message across" in an acoustically crowded environment.

Drongos (Dicruridae) are a group of highly vocal passerines known for their vocal plasticity. In this (ongoing) comparative study of four sympatric drongo species, we aim to understand the breadth of communication strategies used by these birds in presence of other congeners.

Carried out in a lowland tropical evergreen forest in Assam, India, we use active recording of focal drongo individuals. Perch heights of both calling and non-calling individuals were recorded. passive acoustic recorders were used to estimate diel activity patterns. Spatial information was collected along with abundance estimation. Through preliminary analysis, we found significant overlap in their acoustic space. A linear discriminant analysis was done, and a resulting confusion matrix also showed that the model could not accurately distinguish the calls of one species from another. A randomization test revealed that there is significantly higher overlap than is expected by chance. We present evidence of difference in song perch heights in the drongo species, with *Dicrurus hottentottus* occupying the highest perch and *Dicrurus paradiseus* the lowest. There is high overlap in vocal activity time suggesting no temporal partitioning. Further analysis will provide interesting insights into how sympatric drongos coexist in a similar habitat.

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Being flexible in a rigid trait: modulation of Lévy walks in termite workers under distinct social encounter context

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Movement is a crucial element of behaviour: animals displace themselves in space in search of suitable conditions for survival and reproduction. It is hence expected that movement patterns in animals will be determined by the way they efficiently balance (i) their intrinsic individual displacing abilities with (ii) the spatial distribution of food, enemies, mates, etc. However intuitive, this notion needs better evidence, as it lies in the core of the still unsolved mechanisms generating search strategies in animals. That these searches are typically described as a Lévy walk process is consensual, though.

Here we explore such a balance in the context of social interactions among termites. We checked whether changes in the density of nestmates and the density of castes would trigger search-modulation in termite workers of *Cornitermes cumulans* when searching for social interactions. Our results seem to point to a two-fold process. Termite workers confined in petri dishes do displace them- selves in a Lévy-like walking, no matter the density or the type of targets therein present (targets being other workers or soldiers, which do differ in interactivity). Such movements, however, seem fine-tuned by group composition: as the density of workers increases so does the μ exponent of the power law describing the frequency of their step lengths.

In contrast, the mean speed of focal termites decreased exponentially with the increments of both the density of nestmates and the density of termite workers. Whereas indicative of interindividual movement obstruction, these results also point out that such an obstruction is affected by the type of interaction (worker-worker or worker-soldier). It is hence plausible to suspect that their general Lévy displacement pattern would indeed be affected by social interactions more than simply by the obstruction effect of inert targets.

It seems, therefore, that (i) while termites do have an innate propensity to perform Lévy walks, (ii) external constraints, at least in the form of opportunities for social interactions, would add an important modifier to these displacements.

Structural adaptation of group sensitivity

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One advantage of animals living in groups is the ability of the collective to gather (and combine) multiple observations of the environment and share this information within the group. A single individual in a group can thus rely on socially transmitted information (e.g. on the presence of a predator) and adapt its behavior accordingly leading to a group response.

This process of transmission, amplification and filtering of signals has most likely evolved to the requirements of the environment and determines how and which information is shared or ignored.

Theoretical physics suggests that biological systems should have evolved to operate close to a critical point in order to be able to distinguish a large variety of input signals in their behavioral response.

We test his hypothesis in a study of startling cascades in groups of golden shiners for two different contexts (before and after exposure to Schreckstoff, an alarm signal). We model the school's information transfer as a complex contagion process on a vision and distance based network of social interactions and use this model to determine the school's distance from criticality.

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Dominance in habitat preference and diurnal explorative behavior of the weakly electric fish *Apteronotus leptorhynchus*

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Electrocommunication and -localization behaviors of weakly electric fish have been studied extensively in the lab, mostly by means of short-term observations on constrained fish. Far less is known about their behaviors in more natural-like settings, where fish are less constrained in space and time. We tracked individual fish in a population of fourteen brown ghost knifefish (*Apteronotus leptorhynchus*) housed in a large 2 m3 indoor tank based on their electric organ discharges (EOD). The tank contained four different natural-like microhabitats (gravel, plants, isolated stones, stacked stones). In particular during the day individual fish showed preferences for specific habitats which provided appropriate shelter. Male fish with higher EOD frequencies spent more time in their preferred habitat during the day, moved more often between habitats during the night, and less often during the day in comparison to low-frequency males. Our data thus revealed a link between dominance indicated by higher EOD frequency, territoriality, and a more explorative personality in male *A. leptorhynchus*. In females, movement activity during both day and night correlated positively with EOD frequency. In the night, fish of either sex moved to another habitat after about 6 seconds on average. During the day, the average transition time was also very short at about 20 seconds. However, these activity phases were interrupted by phases of inactivity that lasted on average about 20 minutes during the day, but only 3 minutes in the night. The individual preference for daytime retreat sites did not reflect the frequent explorative movements at night.

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Social interactions and environmental conditions lead to opposite preferences between individuals and groups

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Numerous studies on the influence of the physical environment and social interactions on the collective decision-making of groups have showed that interaction between individuals usually amplifies individual preferences. Thus, social interactions can improve discrimination abilities among several options through social amplification of the individual preference when choosing shelter, nest or food resources. Nevertheless, in some cases, individuals and groups show opposite preferences, seemingly in disagreement with the expectations of social amplification. Most social arthropods like cockroaches are able to perform collective decisions when choosing resting places. In this presentation I will explain two cases where isolated individuals and groups display clearly opposite preferences regarding the odor and relative humidity of the shelter or resting place. I discuss how a combination of experimental and modelling work helped disentangle the interplay between individual preference, social interactions, and environmental conditions, and speculate upon the possible proximal mechanisms underlying such an inversion of preferences.

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Using sudden shifts in resource abundance to infer the underlying drivers of sociality

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There is a wide variety of purported benefits to sociality, including an increased ability to find food, avoid predators, and successfully disperse to a new environment. For any particular species, it is usually difficult to determine which of these many potential benefits is the dominant selective force maintaining sociality. For any combination of benefits and costs of sociality, there will be some group size that maximizes fitness (i.e., probability of survival) -- how this optimal group size changes as the abundance of resource in the environment changes, however, is not clear. We modeled a large number of the potential benefits of sociality and examined how, for each benefit, the optimal group size changes when resources change from abundant to scarce (for example, during a sudden drought). We reveal that some benefits result in a decrease in group size, some result in an increase in group size, while still other benefits do not lead to a change in group size. Searching through the empirical literature, we find instances of each of these patterns in nature. Our results suggest that observing how group size changes when resource abundance changes is a simple but potent method to quickly narrow down which of the many benefits of sociality is the dominant one for a particular species.

Spiders, Webs and Soft Robotics

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The spider's web is both a record of the animal's inherited behaviour algorithm and a highly functional extension of the spider's body phenotype. Each thread joint in the structure is carefully placed by the animal to create the correct structural geometry. Because the web is primarily a well-adapted fly-trap, web construction is foraging behavior. The solidified foraging path consists of a long sequence of integrated movement and manipulation patterns that have been terminated long before any prey is caught. Thus web-building is a long-term phylogenetic response rather than a short-term immediate reaction to prey - albeit with scope for some day-to-day fine-tuning adaptations.

In essence, web morphology is the phenotypic embodiment of the spider's way-finding and thread-placement decision rules, which in turn allow for corrections such as detours in the spider's transient path in order to appropriately position the lasting thread junctions.

Rather than depend solely on core hardware (i.e. body) the functional unit of spider-plus-web outsources certain phenotype features to software (i.e. behaviour). Such extended anatomy features are economically cheap and provide responsive flexibility as well as increasing the reach of the animal's basic anatomy/morphology. The concept of behaviour contributing to the overall body plan of an animal can provide inspiration for bio-inspired robotics. For example, consider a robot able to use integrated additive manufacturing ad hoc to extend and expand the physical boundaries of its hard shell.

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Intra-specific behavioural change in resource-manipulated environments of *Neolamprologus multifasciatus*

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When resources become limited in animal groups, costs may be disproportionately felt by individuals in different social positions. As such, conflict between or within particular social classes may increase under conditions of resource limitation but be unaffected in other classes. Here we explore how inter- and intrasexual conflict is mediated by reduction in the availability of breeding sites in a communally breeding Cichlid fish. Small groups of *Neolamprologus multifasciatus* were presented with a foreign male or female conspecific in Lake Tanganyika while the amount of shells (which act as breeding shelters) in the nest was manipulated. Using machine learning assisted tracking and behavioral analysis, we then measured all interactions among group members and towards introduced conspecifics. Aggression among females was predicted to be higher when resources were limited due to higher relative costs than for males, for whom aggression was expected to be unaffected by resource reduction. Inter-sexual interactions were more complex, with males expected to respond more aggressively to foreign males and resident females, but show more courtship to foreign females, when resources were increased. In contrast, female responses to males were predicted to be unaffected in all conditions. Understanding how social group interactions are mediated by fluctuations in resource availability offers insight into the mechanisms of selection on social behaviour generally.

Maternal care: the mother of cooperation between animals

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Cooperation is widespread and we now have a solid theoretical understanding of how it can evolve. However, cooperation in animals is not a single trait behaviour, but includes offspring care, coalitionary support, hunting, or food sharing. While the evolution of these diverse forms of cooperation is associated with different ecological, life-history, and social factors, their proximate regulation appears to uniformly rely on hormones from the oxytocin-mesotocin family, and prolactin. These neuro-hormones regulate maternal and paternal care, which includes diverse behaviours (incubating eggs, social tolerance, offspring protection, food provisioning, prolonged offspring care). Remarkably, the same set of hormones facilitates reproductive cooperation by helpers and allo-mothers, as well as cooperative behaviours outside the reproductive context. Thus, maternal care has a fundamental but so far underappreciated role in the evolution of cooperation. Based on these shared mechanisms, we propose the "Mother of Cooperation" hypothesis, stating that maternal care enables the evolution of reproductive cooperation and many other forms of cooperation in animals, with repercussions for behaviour and psychology. Our hypothesis fills gaps in our knowledge concerning the ecological, social and life-history drivers of cooperative behaviours, and provides a unifying evolutionary framework to understand the evolution of cooperation in animals.

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Being flexible in a rigid trait: modulation of L´evy walks in termite workers under distinct social encounter context

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Movement is a crucial element of behaviour: animals displace themselves in space in search of suitable conditions for survival and reproduction. It is hence expected that movement patterns in animals will be determined by the way they efficiently balance (i) their intrinsic individual displacing abilities with (ii) the spatial distribution of food, enemies, mates, etc. However intuitive, this notion needs better evidence, as it lies in the core of the still unsolved mechanisms generating search strategies in animals. That these searches are typically described as a L´evy walk process is consensual, though.

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Testing the effects of enforced monogamy and polyandry on reproductive success in a field cricket

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Our understanding of sexual selection as an evolutionary force cannot advance without integrating the effects of pre- and post-mating sexual selection. However, the question of how interactions between pre- and post-mating selection shape the evolutionary diversification of reproductive traits remains unsolved. Since pre-mating selection is favoured in monogamous mating scenarios when access to females is reduced and female re-mating rates are low, and post-mating selection is favoured in polygamous mating scenarios with high female re-mating rates, pre- or post-mating traits could be favoured depending on the number of available mating partners. This could lead to different fitness benefits for females, as it is expected for polyandrous females to show higher reproductive output than monogamous females, due to genetic variation. In this study I will address the question of whether monogamous or polyandrous behaviour in the field cricket *Gryllus bimaculatus* affects reproductive fitness in females, by inducing three different types of treatments. To impose pre-mating or post-mating sexual selection female crickets were either mated polyandrously with three consecutive males (post-mating selection); or monogamously three times with the same male, but allowed to choose their partner out of three competing males (pre-mating selection), or they were mated monogamously with no choice (no sexual selection).

I will present results on the effects of the different mating treatments on female reproductive fitness (fecundity, fertility, survival) and offspring quality (size and growth rates).

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Intentionality in chimpanzee vocal communication

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Comparing the cognitive abilities involved in communication between humans and primates can help to understand the evolution of language. One of the most debated topic in those comparative studies is the degree of intentionality displayed by primates, especially great apes, when they produce specific signals. Studies have shown that primates were able to produce certain gestures and vocalisations in a goal directed way (first-order intentionality) but the evidence that they possess the ability to communicate according to others' mental state (second-order intentionality) is still very thin and criticized. The aim of my Ph.D. project is to identify the cognitive processes involved in chimpanzee communication in different contexts. I collect observational data during traveling, resting and feeding events to try and determine if the vocal signals used in these contexts (rest hoo, travel hoo, food grunt and pant hoot) present criteria for first order intentionality. I also conduct an experimental study using presentation of model snakes and playbacks to investigate if chimpanzees are able to attribute a state of knowledge to other individuals and to communicate accordingly. My preliminary results show that the time spent with a social partner seem to influence the production of rest hoos hence playing a role in group cohesion. The production of food calls appear to depend on the context (joining or being joined in a feeding tree) and the rank of the signaler and would be used to advertise rank and assert dominance.

Investigating how baboon behaviour and ecology contributes to Guinea worm transmission in Ethiopia

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While the use of animal models to examine human disease and the study of animal behaviour in response to disease are widespread, the concept of understanding animal behaviour to inform control of human disease remains largely unexplored. An increasing number of 'human' neglected tropical diseases are being detected in non-human primates, indicating that insights into how wild animals contract and transmit such diseases may be crucial to disease management and eradication. We investigate the behaviour and ecology of a social species, the olive baboon (*Papio anubis*), in Gambella, Ethiopia to test the hypothesis that Guinea worm disease (dracunculiasis) may persist in the region due to human-animal transmission. We combine observations of social behaviour from six focal troops with ranging data over 12 months from manual tracking and GPS collars, and dietary data from stable isotope analyses of whiskers to elucidate how baboon behaviour puts them at risk of Guinea worm infection. By linking these behavioural, dietary and ranging information to data on infection history obtained from serology tests of blood samples from individuals, we assess whether certain individuals are more likely to contract and transmit dracunculiasis due to their social position/rank and associated foraging behaviours and/or access to resources. Information on baboon interactions (drinking, eating fish/frogs) with water bodies also used by humans will be particularly informative for control efforts. Our work provides important evidence to inform the new frontier of Guinea worm eradication, plus broader insights into the role non-human social species may play in transmission of human disease.

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Information flow during group decision making in fish

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Quantifying how information spreads within mobile groups and how this subsequently affects group performance are important steps towards understanding the benefits of behaving collectively. Yet previous works have lacked a standardized measure of information flow. The recent development of a method aiming to quantify the gains (or loses) of predictability about a fish trajectory given another fish trajectory data - termed as transfer entropy - has enabled us to identify and quantify predictive information flows from the trajectory data of an entire group. By quantifying how information flows in space and time, the use of transfer entropy allows to consider information dynamics during group decision making. In a Y shaped maze, we tested different group sizes of mosquitofish (*Gambusia holbrooki*) to determine their ability to make an adaptive decision by avoiding the maze arm containing a predator model. Using trajectory data, we quantified the information flow inside the group and found an important effect of group size, with larger groups having greater values of transfer entropy. Investigation of the relationships between transfer entropy, speed and distance to the decision zone will be used to explain the ability of the group to accurately avoid the predator.

An agent-based model to simulate the formation of self-assembled structures in army ants

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Army ants of the genus *Eciton* join their bodies together to create self-assembled structures that are responsive to traffic and environmental conditions, and function as a kind of living infrastructure for the colony. Here I present an individual-based model that simulates the formation and growth of two kinds of structures, bridges and flanges. These two structure types form under different conditions in nature, and the model reproduces both cases, as the same underlying set of individual-level rules results in different structures depending on the geometry of the environment. In the model, ants interact with the environment by detecting the surface ahead (either a void, solid surface, or an ant structure), and the concentration of pheromone deposited by other ants. Mobile ants interact with others encountered within a sensory zone representing the antennae and legs, and ants within a structure can sense contacts from other ants passing over the structure. The model takes three inputs corresponding to variables measured from experimental data: the overall rate of traffic flow; the proportion of ants carrying prey; and the proportion of bidirectional traffic. With these inputs, I test the model under different environmental conditions corresponding to two different experimental setups, for bridges and flanges. Within certain ranges of behavioral parameter values, structures of similar size, geometry, and growth dynamics emerge for both bridges and flanges when compared to experimental data given the same traffic conditions, and I show which parameters appear to be important for the formation of stable and responsive structures.

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