Research Group Prof. Dr. Jonas Rose

Master Project 1: Pigeon Saliency Discrimination & Extinction Learning

The overarching goal of this project is to investigate how the saliency of a context influences extinction learning in pigeons. In extinction learning, an individual acquires a behavior in a certain context, e.g. a pigeon pecking on a specific stimulus. After changing the context, the stimulus no longer gives the desired reward. This is where extinction learning occurs: The pigeon will stop pecking on this stimulus. However, if the pigeon is now transferred back to the original context, they spontaneously show the previous behavior again, which is called renewal (Bouton et al., 2012).

In a series of different experiments, we are probing what ‘context’ means to the pigeons and if classic learning principles apply to the ability of the pigeon to use stimuli as context (Elsner & Hommel, 2004). Following this reasoning, the saliency of a context should influence the extinction and renewal of the pigeons. In this experiment, we would first establish a saliency discrimination curve (Hodos et al., 2002), using sine wave grating images and go/no go task (Kalt et al., 1999). After, those stimuli are used in our extinction learning paradigm (Peschken et al., 2025).

Literature:

Bouton, M. E., Winterbauer, N. E., & Todd, T. P. (2012). Relapse processes after the extinction of instrumental learning: Renewal, resurgence, and reacquisition. *Behavioural processes*, *90*(1), 130-141.

Elsner, B., Hommel, B. Contiguity and contingency in action-effect learning. *Psychological Research* 68, 138–154 (2004).

T Kalt, B Diekamp, O Güntürkün. Single unit activity during a Go/NoGo task in the “prefrontal cortex” of pigeons. *Brain Research*, Volume 839, Issue 2, 1999, Pages 263-278,

Hodos, W., Ghim, M.M., Potocki, A. *et al.* Contrast sensitivity in pigeons: a comparison of behavioral and pattern ERG methods. *Doc Ophthalmol* 104, 107–118 (2002).

Juan Medina Peschken, Lukas Hahn, Roland Pusch et al. Context is Learned, not Given, 09 January 2025, PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-5682968/v1]

Supervision: Farina Lingstädt (M.Sc.), Prof. Dr. Jonas Rose

Master Project 2: Memory and Attention Interaction

We aim to continue studying the neuronal correlates of attention and working memory in birds. Building on the laboratory's comparative cognition work, showing that cognitive capacities are similar in birds and mammals (Hahn et al, 2021, Apostel et al 2023), we will investigate the boundaries between attention and working memory, two processes closely related, interactive, and often complicated to disentangle.

The student will help developing and test a behavioural paradigm like in Messinger et al. 2009, adapted to freely moving birds. Briefly, the animal stays in the centre of the arena and a known target appears in a random location, which the animal needs to remember. The target will start moving around the arena and the bird must attend to it. After a random amount of time the target disappears, and one out of two possible cues is shown: one cue instructs the bird to report the <u>initial</u> location of the target while the other requires reporting about the <u>last</u> location. The animal choice is to move towards a spatial location and, if correct, the animal is rewarded. The target's trajectory would initially be short and predictable, with a possibility for longer, non-predictable or semi-hidden trajectories, increasing the attentional demands and testing for predictability capacities.

With this paradigm we aim to:

- Evaluate if birds can hold a single spatial location in working memory while engaging with an attentive task.
- Evaluate for how long and under what amount of attentional demand they can hold it.
- Test the hypothesis that, when the recollection of initial location is required, an increase in reaction time will be measured, compared to reporting the last seen location.
- Test the hypothesis that trajectory predictability would increase the number of correct reports.
- Check the fitness of the paradigm for further electrophysiological research, where we would record neuronal populations while performing the task.

The student is expected to help refining the task, and train the birds, perform the experiments, and analyse the data. There is the option of participating on the preparations for electrophysiological recordings. Skills that would help are experience handling animals and programming experience in Matlab. These could be acquired over the course of the project.

References:

Hahn, LA., Balakhonov, D., Fongaro, E., Nieder, A., and Rose, J. 2021. Working memory capacity of crows and monkeys arises from similar neuronal computations. Elife, 10, e72783. https://doi.org/10.7554/eLife.72783

Apostel, A. Panichello, M., Buschman, TJ. and Rose, J. 2023. Corvids optimize working memory by categorizing continuous stimuli. Communications biology. 6 (1) 1122. https://doi.org/10.1038/s42003-023-05442-5

Messinger, A., Lebedev, MA., Kralik, JD. and Wise SP. 2009. Multitasking of Attention and Memory Functions in the Primate Prefrontal Cortex. Journal of Neuroscience, 29 (17) 5640-5653. https://doi.org/10.1523/JNEUROSCI.3857-08.2009

Supervision: Prof. Dr. Jonas Rose, Dr. Jesus J. Ballesteros

Master Project 3: Neural correlate of foraging path optimization in birds

One of the most well researched problems in mathematics and computer science is the Traveling Salesman Problem (TSP): a traveler needs to find the shortest route to visit a set of cities, generally, returning to the starting one. The increase in the number of locations to visit is accompanied by an exponential rise in the total number of possible trips. So far, it hasn't been found a single algorithm which always generates the optimal route, within a short computational time. However, humans and other animals easily find very efficient solutions to practical applications of this problem. Hence, it is relevant to investigate what processes underly this level of performance. This project aims to investigate neuronal mechanisms underlying path optimization, in freely moving birds. The foraging paradigm used is an adaptation of the TSP, implemented in a large arena.

In this project, you will:

- Program in MATLAB
- Handle and train birds
- Collect electrophysiology data with a wireless system
- Analyze single-cell data

Note: Familiarity with programming in MATLAB is a necessary requirement for involvement in this project

References:

Hales, J. B., Petty, E. A., Collins, G., & Blaser, R. E. (2021). Contribution of the hippocampus to performance on the traveling salesperson problem in rats. *Behavioural Brain Research*, *405*, 113177. https://doi.org/10.1016/j.bbr.2021.113177

Supervision: Prof. Dr. Jonas Rose

Master Project 4: Category learning with RUBubbles – interactions between the avian striatum, hippocampus and nidopallium caudolaterale

Categorization, the ability to group stimuli in the environment based on perceptual similarity, is a crucial cognitive ability to successfully interact with the detailed environment one lives in. Two jackdaws (*Corvus monedula*) were trained in a delayed match to category paradigm (see Apostel et al., 2024), that used RUBubbles (Apostel and Rose, 2022) as stimuli. To introduce the categories, the birds were either shown a distinct prototype or multiple exemplar images. At every experimental session, the birds were required to learn a new category.

Following the traditional categorization network, we plan to collect data in the jackdaw's nidopallium caudolaterale (NCL), hippocampus and striatum. This project aims to investigate the change in dynamics of those three regions related to the birds learning the categories.

In this project, you will:

- Program in MATLAB
- Handle and train jackdaws
- Collect electrophysiology data
- Analyze single-cell data

Note: Familiarity with programming in MATLAB is a necessary requirement for involvement in this project

References:

Apostel, A., Rose, J. RUBubbles as a novel tool to study categorization learning. Behav Res 54, 1778–1793 (2022). https://doi.org/10.3758/s13428-021-01695-2
Apostel, A., Hahn, L.A. & Rose, J. Jackdaws form categorical prototypes based on experience with category exemplars. Brain Struct Funct 229, 593–608 (2024). https://doi.org/10.1007/s00429-023-02651-w

Supervision: Prof. Dr. Jonas Rose

Master Project 5: Establishing Visual Priming Effects as an Implicit Measure of Invariant Object Recognition in Pigeons

Invariant object recognition is the ability to correctly assign labels to objects although an object's appearance may vary drastically with the viewpoint of the observer and with background changes. In mammals, this abiity is ascribed to a hierarchy of visual cortical stuctures in the 'ventral stream' that builds selectivity for increasingly complex features as well tolerance to indentity-preserving image variation. While the bulk of object recognition research has focused on primates, it is crucial that we also test the generality of object recognition theories outside the cortex. Birds are ideal candidate species for achieving this, as they are highly visual animals and have evolved a nuclear brain. To conduct meaningful comparisons between mammals and birds, it is relevant to adhere to standardized experimental procedures to ensure that differences between species are attributable to differences in brain function rather than to poorly matched task demands. We have recently tested pigeons in a paradigm inspired by rodent research (Zoccolan et al., 2009) and found that pigeons show object recognition behavior similar to rats. When tested explicitly with novel appearances of previously learned objects, both species achieved above-chance object recognition across a variety of object transformations but their performance also decreased as a function of transformation magnitude. In this project, we aim to analyse priming effects as an implicit measure of object recognition using a protocol outlined in Tafazoli et al. (2012): At the core of this protocol is a behavioural task involving a discrimination between two objects presented at different morph levels. Subjects will eventually be tested across a diverse set of priming conditions where either a default view or a transformed (e.g., rotated) view of one of the learned objects is flashed immediately before the presentation of the morph stimulus. The effectiveness of each prime can be estimated based on how reports of object identity shift towards the identity the flashed object. As the primes are always task-irrelevant and presentation times are kept at subliminal durations, we can interpret the effects associated with various object views as a proxy of their perceived similarity in the absence of explicit learning.

For this project, programming in Matlab is needed for the implementation of the paradigm and the data analysis. A good understanding of different statistical approaches is required as well. We furthermore expect the student to work hands-on with pigeons during animal training and data collection and to take responsibility for the birds for the duration of the experiment.

If you are interested in this project, please send an email to: Annika.Verfers@rub.de

References:

Tafazoli, S., Di Filippo, A., & Zoccolan, D. (2012). Transformation-tolerant object recognition in rats revealed by visual priming. *Journal of Neuroscience*, *32*(1), 21-34.

Zoccolan, D., Oertelt, N., DiCarlo, J. J., & Cox, D. D. (2009). A rodent model for the study of invariant visual object recognition. *Proceedings of the National Academy of Sciences*, *106*(21), 8748-8753.

Supervision: Annika Verfers (M.Sc.), Prof. Dr. Jonas Rose

Master Project 6: Extinction Learning in Humans, A Comparative Replication of a Pigeon Study

Extinction learning is a fundamental process through which organisms learn that previously learned associations are no longer valid. Understanding how extinction is acquired and maintained is important for theories of learning, behavioral flexibility, and adaptive decision-making. While extinction learning has been extensively studied in both humans and animals, direct comparisons across species using comparable paradigms remain relatively rare.

In this project, the student will help adapt an extinction learning paradigm previously developed and tested in pigeons for use with human participants. The goal is to replicate the main findings of the animal study and evaluate whether similar behavioral patterns emerge in humans. The project will involve adapting the existing experimental design to a human computer-based task, recruiting participants, collecting behavioral data, and analyzing the results.

The project aims to:

- Adapt a validated pigeon extinction learning task for human participants.
- Replicate the main behavioral findings obtained in pigeons.
- Compare learning and extinction dynamics across species.
- Evaluate the suitability of the paradigm for future comparative cognition research.

The student is expected to participate in the development and testing of the human task, participant recruitment, data collection, and statistical analysis. Useful skills include basic programming experience (e.g., Matlab, or similar), interest in experimental psychology and animal cognition, and basic knowledge of statistical data analysis. These skills can also be acquired during the project.

Literature:

Peschken, J., Hahn, L.A., Pusch, R. *et al.* Extinction context is learned by pigeons, not given by the environment. *Commun Psychol* 3, 83 (2025). https://doi.org/10.1038/s44271-025-00261-2

Donoso, J.R., Packheiser, J., Pusch, R. *et al.* Emergence of complex dynamics of choice due to repeated exposures to extinction learning. *Anim Cogn* 24, 1279–1297 (2021). https://doi.org/10.1007/s10071-021-01521-4

Juan Peschken. Context Emergence through Stimulus Competition in Extinction Learning, 19 March 2025, PREPRINT (Version 1) available at Research Square https://doi.org/10.21203/rs.3.rs-6146552/v1

Supervision: Juan Peschken (M.Sc.), Prof. Dr. Jonas Rose