Research Group Prof. Dr. Jonas Rose

Master Project 1: It's all about the "he said, she said"

Are Corvids able to distinguish between different members of their species just by hearing them? A playback-based study investigating potential individual signatures in jackdaws *Corvus monedula*.

Corvids belong to the systematic group of songbirds (Passeri). Songbirds are able to produce a variety of calls and have the ability to learn vocalizations through their parents or other tutors. Especially corvids can learn new calls over their lifetime and not only as juveniles. In the last decades, research on corvids has shown that they have cognitive abilities comparable to highly cognitive mammals like primates. Additionally, jackdaws live in huge flocks consisting of up to a thousand individuals. This makes them a well-suited model organism to study social cognition and vocal cognition. The high sociality of these birds leads to an interesting thought: If you want to communicate in a complex group context to a specific individual, it is important to know your target and to be able to selectively target it in the communication process. This leads us to the question: Are jackdaws able to identify specific birds and target them through vocal signatures, like some songbirds, mammals, and humans do?

In this study, we try to test if our birds can identify a known bird only by hearing a call from it. To do so, we will separate individuals from the flock and use playback sounds to test the reaction of the flock. We have already established an AI-based, reactive recording and playback system which makes it easy to play calls precisely as a reaction to the flock's vocal communication.

If you are interested in working together in a team focused on different aspects of the vocal behavior of our jackdaws, and if you are interested in behavioral studies, analyzing big data, AI and programming, cognition of vocalization/language/communication: This could be your thesis.

Experience in MATLAB or general programming is required! You do not have to be a software engineer, but you should be able to understand and use tools that already exist and adapt them to your tasks over time.

Supervision: Lutz Wehrland, 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 initial location of the target while the other requires reporting about the last 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.

Referenced papers:

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: Probing the limits of pigeons' abilities to categorize artificial stimuli

Categorization is an important cognitive ability that allows us to handle the endless amount of sensory input in our everyday life. Instead of consciously assessing every single detail, we group objects based on their perceptual similarities into categories, such as cars, trees, houses and so on. Birds, such as pigeons, possess similar abilities (see Güntürkün et al., 2018). In many studies on categorization, morphs between two prototype stimuli are used to determine where the participant / animal would draw the category boundary (see cat-dog morphs in Freedman et al., 2001). To eliminate previous or instinctive associations with the given stimuli, artificial stimuli (such as the RUBubbles stimuli; see Apostel & Rose, 2022) can be used.

In this project, you will design such RUBubble morphs using available Matlab code. Then, you will use these to train pigeons on a categorization paradigm, to determine if they can categorize the 'ambiguous' stimuli in the middle of the morph. To really probe the limits of pigeon categorization abilities further manipulations of the stimuli might be necessary. This can include for example rotating the stimuli or making them even more abstract, to find out what determines a category in the view of a pigeon. Concretely, this project will involve designing RUBubble stimuli and coming up with an adaptive approach to change and manipulate them until the limits of the abilities of the pigeons are reached. This means that you will use / program Matlab code as well as handle and train pigeons.

Literature:

Apostel, A. & Rose, J. (2022). RUBubbles as a novel tool to study categorization learning. *Behavior Research Methods, 54*, 1778-1793.

Freedman, D. J., Riesenhuber, M., Poggio, T., & Miller, E. K. (2001). Categorical representation of visual stimuli in the primate prefrontal cortex. *Science, 291*, 312-316.

Güntürkün, O., Koenen, C., Iovine, F., Garland, A., & Pusch, R. (2018). The neuroscience of perceptual categorization in pigeons: A mechanistic hypothesis. *Learning & Behavior, 46*, 229-241.

Supervision: Farina Lingstädt, Prof. Dr. Jonas Rose

Master project 4: Which feature of artificial stimuli do pigeons use to determine category identity?

Categorization is an important cognitive ability that allows us to handle the endless amount of sensory input in our everyday life. Instead of consciously assessing every single detail, we group objects based on their perceptual similarities into categories, such as cars, trees, houses and so on. Birds, such as pigeons, possess similar abilities (see Güntürkün et al., 2018). While multiple features jointly determine category identity, it is possible to investigate which features drive the categorization of pigeons the most (see Aust & Huber, 2002). This can be especially important, when using artificial stimuli, that are made up of many different dimensions, such as the RUBubbles, which consist of an arbitrary number of colored spheres that are arranged in a three-dimensional space (see Apostel & Rose, 2022).

In this project, you will first go through the RUBubbles stimuli and how they are designed to determine possible relevant dimensions. Then you will derive a way to systematically probe whether those features are relevant to the pigeon or not. Even though this is not planned as a neurophysiological study, you should take into account the visual stream of the pigeon (see Azizi et al., 2019) and on which hierarchical level which features are processed. This can inform your theories on when / how a category is no longer recognized by the pigeon. You will use / program Matlab code as well as handle and train pigeons.

Literature:

Aust, U. & Huber, L. (2002). Target-defining features in a “people-present / people-absent” discrimination task by pigeons. *Animal Learning & Behavior, 30(2)*, 165-176.

Azizi, A. H., Pusch, R., Koenen, C., Klatt, S., Bröker, F., Thiele, S., Kellermann, J., Güntürkün, O., & Cheng, S. (2019). Emerging category representation in the visual forebrain hierarchy of pigeons (*Columba livia*). *Behavioral Brain Research, 356*, 423-434.

Güntürkün, O., Koenen, C., Iovine, F., Garland, A., & Pusch, R. (2018). The neuroscience of perceptual categorization in pigeons: A mechanistic hypothesis. *Learning & Behavior, 46*, 229-241.

Supervision: Farina Lingstädt, Prof. Dr. Jonas Rose

Master project 5: Head and Eye Movements in Unrestrained Birds

Animals use vision to gather information about their environment, which allows them to make behavioral decisions. They will often move their heads or eyes to inspect areas of interest. Animals with laterally placed eyes display different patterns of ocular movement, compared to the saccadic motion, observed in animals with frontally placed eyes (Tyrrell et al. 2014).
It has been methodologically challenging to control for the gaze direction of birds, during the performance of cognitive tasks. There is a lack of data when it comes to the quantification of the degree to which different species move their eyes, relative to their head direction. Therefore, few studies to date have been able to accurately determine where laterally eyed animals direct their visual attention.
Recently, the NGL lab has established an eye-tracking procedure, based on computer vision algorithms. The masters project here proposed aims to use this technology to quantify the degree of eye movement, relative to head position, in two different bird species: the pigeon (*Columba livia*) and the jackdaw (*Corvus monedula*).

In this project, you will:
- Program in MATLAB (paradigm implementation, data collection and analysis)
- Handle and train birds.

References:
Wohlschläger, A., Jäger, R., & Delius, J.D. (1993). Head and eye movements in unrestrained pigeons (Columba livia). *Journal of Comparative Psychology, 107*, 313-319.
Kano, F., Naik, H., Keskin, G. *et al.* Head-tracking of freely-behaving pigeons in a motion-capture system reveals the selective use of visual field regions. *Sci Rep* **12**, 19113 (2022). https://doi.org/10.1038/s41598-022-21931-9

Supervision: Sara Santos Silva, Prof. Dr. Jonas Rose