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).

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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 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.

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: 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 (M.Sc.), Prof. Dr. Jonas Rose

Master Project 4: Using Rapid Serial Visual Presentation to Analyze the Processing Speed of Pigeons during Object Recognition

Our brain allows us to recognize thousands of objects within a split second, and it does that with seemingly little computational effort. However, this ability must not be taken for granted. The high speed and accuracy that characterizes our visual system has so far only been observed in primates and requires a series of visual cortical structures in the 'ventral stream' that uses hierarchical processing to extract features of increasing complexity and with growing invariance to the observer's viewpoint. There is behavioral and neuronal evidence to suggest that a single feed-forward pass along the ventral stream suffices to make categorical information accessible for downstream areas, and that this enables us to recognize objects at above-chance level after seeing them for just ~15 ms (Keysers et al., 2001k). While the ventral stream's approach to visual processing is doubtlessly very efficient, a strong research focus on primates has led us to ignore the possibility that other species outside the research spotlight might match or even exceed primate performance in object recognition tasks. From an evolutionary perspective, birds can be assumed to have evolved a powerful visual system as they heavily depend on visual information during foraging activities, predator avoidance, navigation, or social interaction. Moreover, birds are an interesting model for vision science because of their brain organization. Rather than consisting of cortical layers, the avian brain is organized into nuclear clusters, which opens a unique window into the links between brain structure and function.

The main goal of this project is to quantify the speed of object recognition in pigeons using a rapid serial visual presentation paradigm. That means that we will present images to the subjects that depict objects from different perspectives while manipulating the duration each object stays on screen. This will enable us to address some interesting questions about the optimization of visual processing in the avian brain: How does the avian visual system trade off speed and accuracy when disentangling different object identities? To which extent are pigeons affected by restrictions of viewing duration, and what does this teach us about the efficiency of their (hierarchical?) visual processing? And finally, how is visual processing speed affected by alterations of object appearance?

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:

DiCarlo, J. J., Zoccolan, D., & Rust, N. C. (2012). How does the brain solve visual object recognition?. *Neuron*, *73*(3), 415-434.

Keysers, C.; Xiao, D.-K.; Földiák, P.; Perrett, D. I. . (2001). The Speed of Sight. *Journal of Cognitive Neuroscience, 13*(1), 90–101.

Supervision: Annika Verfers (M.Sc.), 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 ability is ascribed to a hierarchy of visual cortical structures in the 'ventral stream' that builds selectivity for increasingly complex features as well as 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 in brain organizations other than the cortex. Birds are ideal candidate species for achieving this goal, as they are highly visual animals and have evolved a nuclear brain without a cortex. 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 achieve above-chance object recognition across a variety of object transformations but also show decreasing performance as a function of transformation magnitude. We next aim to analyze priming effects as an implicit measure of object recognition. The study will follow a protocol outlined in Tafazoli et al. (2012): Following discrimination training involving two artificial objects in a default view, subjects learn to apply the discrimination to a series of morph stimuli, forming a continuous shape dimension. Along that shape dimension, the probabilities of reporting each object identity is expected to follow a binomial function. Subsequently, subjects will be tested in priming conditions where either a default prototype view or a novel transformed view of one of the learned objects is flashed before the morph stimulus appears. Priming effects can be quantified by measuring how much the binomial curve shifts towards the identity of the prime. The similarity of priming effects evoked by the default vs the transformed objects views can be interpreted as a measure of the perceived similarity between the primes that is free from the influence 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