MASTERARBEIT | MASTER'S THESIS

Titel | Title

Exploration and feeding in Greylag Geese when threatened with an artificial predator

verfasst von | submitted by

Marion Lehner BSc

angestrebter akademischer Grad | in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien | Vienna, 2025

Studienkennzahl lt. Studienblatt | Degree programme code as it appears on the student record sheet:	UA 066 878
Studienrichtung lt. Studienblatt | Degree programme as it appears on the student record sheet:	Masterstudium Verhaltens-, Neuro- und Kognitionsbiologie
Betreut von | Supervisor:	Assoz. Prof. Mag. Dr. Petra Sumasgutner

Table of Content

1. Acknowledgement

I would like to express my sincere appreciation to my professor, Petra Sumasgutner, for her invaluable supervision throughout my thesis. Her guidance and support during the whole writing and analysis phase were essential for the success of this work.

I would like to extend my thanks to the Konrad Lorenz Research Center (KLF) for the opportunity to participate in such a great experiment and for allowing me to observe their exceptional work in action. I am truly grateful for the incredible chance to pursue this master's degree in cognitive and behavioral biology and would like to thank the University of Vienna for allowing me to study at this institution.

I would also like to acknowledge Marc Surlemont BSc., whose assistance and collaboration were crucial whenever I encountered challenges and was always available when something was unclear. Thanks to my sister, Sara Lehner BSc., for her mental support and encouragement, which helped me stay motivated throughout this journey.

2. Abstract

Exploration is commonly defined as the inclination to investigate novelty, whether in a new habitat or in response to an unfamiliar object, with animals typically reacting either with curiosity (neophilia) or with fear and avoidance (neophobia). In feeding-related contexts, exploratory tendencies can be assessed by observing whether animals alter their feeding behavior in the presence of a novel item, revealing varying levels of neophobia. Linking neophobia to exploration provides a framework to examine individual differences in food neophobia and how these may influence foraging behavior. Thus, the aim of this study is to generate an exploration score based on the Delta Latency values from a previous novel object test and observe the influence on the behavioral responses, particularly feeding time allocation. In an experimental set up in Grünau im Almtal, 61 semi - tame greylag geese (*Anser anser*) were exposed to an artificial predator (RobotFalcon), and their responses to the threat were observed. Results show that individuals with a lower exploration score (more neophobic) spent less time feeding, whereas those with a high exploration score (less neophobic) spend more time foraging, but only during the before launch phase within the experiment. This indicates a positive correlation between exploration and feeding time budget, suggesting that neophobia influences foraging behavior. The study also investigates whether feeding and vigilance correlate, where an increase in one parameter leads to a corresponding decrease in the other. The findings support a trade-off between feeding and vigilance, especially shown in the presence of a threat, heightened alertness was associated with reduced feeding behavior. In summary, exploration influences the feeding time but does not directly affect vigilance responses under threat. Individual behavioral responses are shaped by the perceived level of risk, leading to shifts in time allocation between feeding and vigilance. This study highlights the complexity of a behavior under a given threat, which is crucial for understanding how animals balance their action in the face of potential predator. Hence, this reveals how personality influences survival strategies and decision making in wildlife under ecological stressors.

Keywords: Greylag Geese (*Anser anser*), Exploration, Neophobia, Vigilance, Trade-off

3. Zusammenfassung

Exploration wird allgemein als die Neigung definiert, ein neues Habitat oder ein unbekanntes Objekt zu erkunden, wobei Tiere entweder mit Neugier (Neophilie) oder mit Angst und Vermeidung (Neophobie) auf den Stimulus reagieren. Platziert man eine Futterquelle neben einem unbekannten Objekt, kann dies die explorativen Tendenzen der Tiere beeinflussen. Dabei lässt sich beobachten, ob Tiere ihr Fressverhalten in Anwesenheit eines neuen Gegenstandes ändern, wodurch unterschiedliche Ausprägungen von Neophobie zum Vorschein kommen. Die Verknüpfung von Neophobie mit Exploration bietet daher einen Ansatz, individuelle Futterneophobien und das damit verbundene Fressverhalten zu untersuchen. Ziel der Studie war es, basierend auf den Delta-Latenz Werten aus einem vorherigen Novel Object Test, eine Explorationsskala zu erstellen und den Einfluss von Exploration auf die Fressdauer in Relation zur Ausprägung von Neophobie zu analysieren. In einem Experiment in Grünau im Almtal wurden 61 halbzahme Graugänse (Anser anser) einem künstlichen Raubtier (RobotFalcon) ausgesetzt und ihre Reaktionen auf die Bedrohung wurden beobachtet. Die Individuen mit niedrigem Explorationswert (höhere Neophobie) verbrachten weniger Zeit mit Fressen als Individuen mit einem höheren Explorationswertes (weniger Neophobie), die mehr Zeit für der Nahrungsaufnahme aufnahmen, allerdings nur in der Phase vor dem Prädatorangriff. Dies deutet auf eine positive Korrelation zwischen Exploration und Futterzeitbudget hin und legt nahe, dass Neophobie Einfluss auf das Fressverhalten hat. Darüber hinaus wurde die Korrelation von Fressen und Wachsamkeit untersucht, bei der eine Zunahme des einen Parameters mit einer entsprechenden Abnahme des anderen einhergeht. Die Ergebnisse unterstützten die Annahme eines Trade-offs zwischen den beiden Verhaltensweisen, insbesondere in Gegenwart einer akuten Bedrohung; eine erhöhte Wachsamkeit war mit einer Reduktion des Grasens verbunden. Zusammenfassend lässt sich sagen, dass Exploration mit der Fressdauer korreliert, jedoch keinen direkten Einfluss auf die Wachsamkeitsreaktionen hat. Individuelle Verhaltensantworten werden durch das wahrgenommene Risiko geprägt und dies führt zu einer Verschiebung der Zeitallokation zwischen Fressen und Wachsamkeit. Diese Studie verdeutlicht die Komplexität des Verhaltens unter Bedrohung und liefert wichtige Erkenntnisse darüber, wie Tiere ihre Handlungen angesichts potentieller Raubtiere

ausbalancieren. Folglich zeigen die Ergebnisse, wie Persönlichkeitseigenschaften die Überlebensstrategien und Entscheidungsprozesse im Tierreich unter ökologischen Stress beeinflussen.

Keywords: Graugänse (*Anser anser*), Exploration, Neophobie, Wachsamkeit, Trade-off

4. Introduction

The research on personality has a long-standing history, particularly in humans, where it has been extensively studied to behavioral and psychological outcomes (Ahrndt & Albayrak, 2017). More recently, there has been growing interest in exploring personality in non-human animals (Kaiser & Müller, 2021). A personality trait refers to behavioral differences, which show stability and consistency over time and in various situations, offering valuable insights into ecological and evolutionary consequences of individual responses (Cabrera et. al., 2021; Jones & Godin, 2010). Therefore, there are five personality dimensions – sociability, aggressiveness, exploration, activity and boldness – commonly used to explain behavioral variation within species (Kralj-Fišer et. al., 2007; Réale et. al., 2007).

In this study, the focus is the exploratory personality, measured using either a novel object test (Takola et. al., 2021) or a novel environment test (Huang et. al., 2016). A novel environment test evaluates the tendency to explore a new habitat, with more exploratory individuals taking greater risks, moving freely and visiting more components within the habitat. In contrast, less exploratory animals explore fewer areas and exhibit lower frequency of movement (Jablonszky et. al., 2020).

When animals occupy a familiar habitat, this attempt often fail to detect individual differences in exploration. Instead, presenting animals with novel objects can reveal if individuals react with fear or curiosity towards an unfamiliar item (Mettke-Hofmann, 2012). Measuring the latency to approach the object, allows the quantification of exploratory tendencies, assessing whether individuals are hesitant or eager to investigate novelty (Dalmau et. al., 2009; Bulens et. al., 2015).

A novel object test is particularly suitable for assessing exploratory tendencies in greylag geese (*Anser anser*), inhabiting the well-known and familiar environment of Grünau im Almtal, Upper Austria. Following Kleindorfer et. al. (2024b), this approach presents an unfamiliar item adjacent to a food source and measure how quickly each individual is approaching towards it, thus linking exploration directly to foraging motivation (Kleindorfer et. al., 2024b). This can be measured using a neophobia score or Delta Latency, reflecting differences in latency to feed in the presence of a novel item. High neophobia reflects the reluctance towards a novelty, possibly as a strategy to avoid certain risk and remain save (Crane & Maud, 2017), whereas neophilia is characterized by curiosity towards unknown and is often indicated by a negative

latency, suggesting a faster approach and a higher exploratory tendency (Sih et. al., 2023). Calculating an exploration score helps to link exploration with feeding activity, suggesting that food neophobia may predict how much time individuals spend foraging and indicate whether they are more or less exploratory based on their neophobia levels.

Ecologically, animals with higher exploratory tendencies may benefit from discovering new food sources or feeding opportunities more quickly (Verbeek et. al., 1994), but this advantage can lead to the cost of increased vulnerability to potential threats (Stöwe et. al., 2006a). In contrast, neophobic animals tend to remain in known environment and stick with familiar situations and therefore minimize the change of facing dangerous encounters (Moretti et. al., 2015). This creates a scale where individuals vary in their exploratory behavior, influenced by factors such as prior experience (Kluen et. al., 2022), social relationships (Stöwe et. al., 2006b), dominance status (Dingemanse & de Goede, 2004), fluctuating environmental conditions (Winkler & Leisler, 1999) etc., which shape the expression of personality traits in a context - dependent manner (Réale et al., 2007).

Hence, the measurement of exploration can vary depending on the specific focus and methodology applied. For instance, the neophobia threshold hypothesis suggests that individuals with higher exploratory tendencies may demonstrate enhanced foraging techniques (Tebbich et. al., 2010; Forss et. al., 2017). In the context of this study, exploration is linked to the time budget allocated to foraging, thereby connecting exploratory tendencies to the amount of time spent feeding. This framework allows for the investigation of how neophobia influences feeding behavior, particularly under a perceived risk of predation. Additionally, this approach provides an opportunity to observe whether the two risk appetites exploration and vigilance – are correlated.

A suitable species for further investigation of exploration and vigilance behavior are the greylag geese (*Anser anser)* due to their complex social structures and the variability of personality types within a flock (Kralj-Fišer et. al., 2009). This species exhibits anti-predator-responses, with different alertness states triggered when a predator approaches, typically detected through visual cues (Kavaliers & Choleris, 2001; Fernandez-Juricic, 2012).

Depending on the level of alertness, the behavior varies between high and low vigilance showing different behavioral responses (Kotrschal et.al., 1992). As a result, they are well-suited

for observing alertness and investigating its connection to the personality trait. Observing exploration in a feeding context, particularly under the threat of predation, allows for the assessment of whether feeding and vigilance operate in a trade-off manner, where focusing on the ground compromises the ability to stay alert (Watson et. al., 2007; Jones & Godin, 2010). Building on a previous study from Storms et. al. (2022), the use of an artificial predator enables the investigation of how a potential threat influences the feeding time budget, leading to a possible decrease in feeding behavior while concurrently increasing vigilance (Storms et.al, 2022).

Overall, the objective of this study is to examine exploration scores in relation to the feeding time budget, with the expectation that less neophobic individuals will spend more time feeding. Additionally, the aim was to investigate how geese respond to an artificial predator in terms of the trade-off between vigilance and feeding and how foraging time is influenced by the personality trait of exploration. The trade–off hypothesis suggests that heightened vigilance results in less time spent feeding (Watson et. al., 2007). Ultimately, the research seeks to evaluate the relationship between the personality trait of exploration and foraging behavior under conditions of predation risk.

The hypotheses are as follows:

1. Food neophobia is associated with foraging time budget when exposed to a threat
2. The presence of the Robot Falcon influences the behavioral responses of geese, affecting their vigilance levels and feeding time

Predictions

1. Less neophobic geese (i.e. higher exploration scores) will exhibit longer feeding durations, compared to an individual with a lower exploration score (more neophobic). This relationship will be less apparent under threat during the exposure to an artificial predator
2. There is a negative correlation between vigilance and foraging, whereby in the presence of a predator, geese will spend more time vigilant and less time feeding. This illustrates a trade-off between these two behaviors.

5. Methods

5.1 Delta Latency and exploration score

The exploration personality was evaluated through a novel object test, conducted at the Konrad Lorenz Research Center (Kleindorfer et. al., 2024b). To establish a baseline, the geese were habituated to the feeding trays for three days. On the fourth and fifth day, the baseline latency has been recorded, defined as the time in seconds an individual need to pass a 1-meter mark within a 2-meter zone to access the feeding area.

Following the baseline phase, a novel object such as small and large glass jars filled with different liquids or a coffee mug, was placed next to the feeding stations. The latency was again measured, reflecting how long an individual takes time to approach in the presence of an unfamiliar object. Thus, Delta Latency represents the change in latency to approach the feeding area in the presence of a novel object, compared to the baseline phase without the novel object (Kleindorfer et.al., 2024b). This procedure is essential to assess individual neophobia, providing insights into whether a goose is more or less exploratory in a feeding context. The key exploration values, including the primary metric Delta Latency (Supplementary Figure 1), were derived from the data reported from Common (2024). For this analysis, individuals were classified based on their Delta Latency (also referred to as neophobia latency) by generating exploration scores. These scores were calculated by multiplying the values by - 1, effectively creating an inverse neophobia latency. Hence, a higher exploration score indicates a greater tendency for exploration, while a lower score reflects a weaker tendency with a value range of -2, -1, 0, 1, 2. A total of 53 individuals had an assigned exploration score. They were distributed across the following bins: 15 individuals in bin -2, 14 in bin -1, ten in bin 0, seven in bin 1 and seven in bin 2.

5.1.1 Pairwise comparison and Bonferroni method

A pairwise comparison was done to compare the means between two groups and see if there is a significant difference between them (Abdi & William, 2010). In this analysis, a Tukey-adjusted pairwise comparison was applied to examine differences in exploration scores across each phase with a Bonferroni adjustment to control for multiple comparison (Drezner et. al., 2016).

Subsequently, the estimated marginal means (EMMs) were calculated for the least and the most exploratory geese to enable a comparison between the two specific groups, focusing on how the exploration score correlates with the duration of the behavioral response. Specifically, explorations score -2 and 2 were compared to assess whether feeding duration differed between highly neophobic and highly exploratory geese during the before launch phase (Lenth, 2023). In addition, Tukey-adjusted comparison was conducted across all exploration scores (-2, -1, 0, 1, 2) within each phase – before launch, exposure and after landing, to examine potential differences in feeding duration among the different exploration tendencies.

5.2 Study species and study site

The subject species of this study are the Greylag geese, belonging to the order of Anseriformes which is a widely distributed and notable species. The binomial name is *Anser anser* within the genus Anser and the family of the Anatidae (Scheiber et. al., 2013). The population size of the individuals varies across time but at this study period the total number of geese was n =122. In 1973, Konrad Lorenz settled a flock of geese in an area in Upper Austria, Grünau im Almtal (47° 51′ 12″ N, 13° 57′ 24″ O 47) and research has continued ever since (Kleindorfer, 2024a). The individuals have become accustomed to humans, no longer migrate away from the area and are supplementary fed throughout the year (Supplementary Figure 2). To facilitate accurate identification, colored rings have been placed around the geese's legs. Alongside the ID of the birds, I was provided with a list of sex, age and pairing status of all geese by the KLF. This allows the comprehensive tracking of the complete life history of the geese including the personality types (Réale et. al., 2007), social dynamics (Scheiber et. al., 2013) and dominance status (Wascher et. al., 2012; Kleindorfer et. al., 2024c). The study site was conducted at the Auinger Hof (7°48′49.4″ N 13°56′51.9″ E) where the geese get fed twice per day and therefore various feeding trays have been specially set up to provide the geese with food sources supported by human caretakers (Figure 2). The flock consisted of 122 flock members, but only 62 have been recorded during the experiment. Of these, 55 individuals had consistent data on personality and life history traits, including information on sex, age and pairing status. The age range of these geese spanned from 2 to 21 and approximately 38 % (n = 21) were females while 61% (n = 34) were males. Regarding pairing status, over 78 % (n = 43) of the individuals were paired while nearly 22% unpaired (n = 12).

5.3 Experimental set-up

5.3.1 general information about the experiment

The duration of the experiment was within a two-week time period, from the 29th of July until 10th of August 2024 in Grünau im Almtal, Upper Austria. The location of the experiment was at the old Konrad – Lorenz Forschungsstelle (KLF) known as Auinger Hof, approximately five minutes away by car from the current research center and the Game Park.

The experimental set-up included a feeding area with trays marked A-E and numbered 1-4, to represent specific sectors (Supplementary Figure 2). These markings facilitated the recognition of geese in the videos. The experiment was carried out over eight exposure days, initially from Juli 29th to 31th, and then from August 6th to 8th. Additionally, two more days (9th and 10th of August) were part of the experiment, but were excluded as no focal recordings were collected. The experiment was divided into three distinct phases, the before launch phase (5 minutes) with no Robot Falcon present. The second phase, the exposure phase, involved the artificial predator flying over the flock for 10 minutes, allowing to observe how the geese reacted to the perceived threat. Finally, the after landing phase (5 minutes), served as post-exposure period to assess any behavioral changes after the predator simulation. Over the first three days of the experiment (29th - 31th of July), the exposure phase was marked by randomized stoops, during which the Robot Falcon hovered over the flock in different altitudes. The 1st of August included an experimental set-up where just the artificial falcon launched but without any participants. After a break (2nd – 5th of August) due to avoidance of habituation and rainy weather conditions, which limited the drone's ability to operate because of its low water resistance, the trials resumed at the 6th – 8th August. A new protocol has been designed, involving six structured stoops within designated exposure area measuring 10 meters by 3 meters. In this set-up, the flight altitude of the Robot Falcon was lowered to 0.5 meters above the ground to determine whether the geese would exhibit different reactions. The 9th of August consisted of the geese ID videos during before launch but without focal recording during the exposure phase. Therefore, the total number of the experiment was eight days, but with a variation of the set-up and a lack of the focal geese videos on the 1st and 9th of August. Hence, the analysis of the data consisted of six exposure days.

5.3.2 procedure of the experiment

The geese get food every morning at 8:00 Central European Time (GMT + 2), where the research staff provided the animals with food twice per day at the old KLF area. At this time the participants gathered at the feeding area and the drone exposure trial started. The experiment was divided into several phases, as follows:

After all recording devices were synchronized to the atomic clock, the baseline phase began. The geese were assigned to their respective identities and current position. The “before launch” phase duration was approximately five minutes and lasted until the coordinator of the experiment allocated a specific focal goose to each researcher. The video recording of the focal individual began once all participants had been assigned a focal and initiated the recording simultaneously, using a visual cue- specifically, by moving a hat in front of the camera.
The goal was to track the focal goose throughout the entire video and if there was a partner existing, that partner was also included in the recording. Once each researcher had an assigned focal goose, the monitoring UAV drone was launched, hovering 30 meters above the geese flock. Five minutes after the baseline commenced, the Robot Falcon drone launched. The exposure phases of the drone were subdivided into two different elementary periods:

The first three days (1-3) consisted of “medium-risk” phases where the drone headed towards the river and the old KLF building without any stoop maneuvers, gradually increased the altitude up to 80 meters. On the fourth day, no observers were present to record the flock, resulting in the absence of focal video data and consequently has been excluded from the statistical analysis. The defined “stoop” phases consisted of the drone approached to the geese feeding center at angles of 30-45 degrees, resulting in varying responses from the individuals. The order of the phases was randomized to avoid biases in responses. On the following three days (4-6), a total amount of six stoops within a designated exposure area (10 x 3 meters) were included into the experiment, defined as high-risk phases stooping 0.5 meters above ground.

The final post exposure phase included the withdrawal and the landing time of the falcon drone. Once the robot falcon had landed, a post exposure observation period lasted approximately five minutes took place. At the end of this phase, the research leader signaled the end of the video marked with an acoustic cue. The flock of the greylag geese at the KLF

research center consisted of approximately n = 122 individuals with different pair status, sex and age. Additionally, the personality types of the geese were well studied and had been recorded. In case of the exploration type, studies had been conducted with the novel object test in a given environment (Kleindorfer et. al., 2024b). Previous studies from the researchers of the KLF institute had scored the focal personality types in different axis like aggressiveness, exploration, sociability and boldness (Common, 2024).

5.4 Behavioral Analysis

The analysis of the behavioral data is carried out using the BORIS Program (version 8.27.7) followed by the coding of the specific behavior from a total number of 62 recordings. For the differentiation of the behavioral states, the original ethogram was invented by Konrad Lorenz (Supplementary Figure 3), but for our investigation we used an adapt version, inspired by the findings of Barnas et.al. (2018) (Supplementary Figure 4). The classification differs between movement and vigilance responses. Movement consists of the clusters running, swimming, lying, standing, flying and walking. The vigilance part includes V0 (non-feeding), V1 (short neck), V2 (long-neck), V3 (eye – up posture) and feeding (Supplementary Figure 5). If the individual is not visible, this certain time window counts as out of view (OOV) and will be excluded. The coding of the data is divided between two other master students, Sara Lehner and Marc Surlemont, and is carried out in collaboration.

To differentiate between various vigilance postures (Supplementary Figure 5), accurate discrimination is essential. The non-feeding posture encompasses different behavioral expressions, such as looking at the ground while walking or lying, which are not associated with vigilance. Short neck reflects a moderate level a vigilance characterized by the beak being held straight at a 90-degree angle. In contrast, the long-neck posture signifies a higher level of alertness, with the beak raised upwards. The most intense form of vigilance is the one-eye-up posture, where one single eye focusses on the sky while the head is slightly tilted, allowing the individual to observe a potential predator more precisely. The behavioral coding was coded twice to independently observe the movement and the vigilance behaviors, preventing the simultaneous coding of two different behavioral responses. Furthermore, it allows a better focus on each of the behavioral responses without interference.
From 62 behavioral recordings collected, 53 individuals were selected for the subsequent statistical analysis.

5.5 Statistical Analysis

5.5.1 proceeding the data

The total duration (seconds) of the exposure length varies within the different days of the experiment. For the analysis of the elements, the length on the respective day has been extracted and subsequently created phase boundaries out of this. The exposure duration was as follows: Day 1 - 98 seconds, Day 2 - 138 seconds, Day 3-99 seconds, Day 4-100 seconds, Day 5 - 138 seconds, Day 6-119 seconds. The same duration was extracted for both before launch and after landing phase to ensure equal time length across all three phases.

5.5.2 Statistical tests for the modelfit

R-Studio (Ihaka & Gentleman, 1996) was utilized in this Master thesis in order to statistically compute and effectively visualize data (Kabacoff, 2015). The analysis of the behavioral data was conducted using different combinations of diagnostic tests, data analysis and statistical modeling and each of this testing ensures the validity of the best statistical model.

Focusing on the feeding data, a subset was extracted and underwent a series of checks to evaluate the underlying conditions before fitting the model. Firstly, the Outliers of the response variable (duration) have been identified using z-scores and this involves the detection but not removing extreme values and their deviations from their mean. Potential outliers count as z-scores over 3 and the subsequent detection is essential to avoid extreme values and their eventually huge influences on the model fit and statistical inference (Rousseeuw & Hubert, 2011). Afterwards, the application of the Anderson-Darling (A-D) test has been done to see if its normally distributed. The normality of the response variable shows whether the dataset follows a specific distribution (Romeu, 2003). In this case, the data is not normally distributed and therefore a log transformation has been applied to reduce the skewness and creates a better stabilization of the variances (Osborne, 2010). After the log-transformation, the A-D has been reapplied and subsequently observe if this improved the normality of the response variable.

The next step is to look at the homogeneity of the variances (duration) across the levels of the predictor (response variable (duration) ~ predictor (phase)) and evaluates equality of the

variances across phases (Gastwirth et. al., 2009). Among the predictors, multicollinearity can be detected with the Variance Inflation Factor (VIF), indicating whether a high multicollinearity (VIF above 5 or 10) or a low values with a decrease of collinearity (Murray et.al., 2012). The VIF for the predictors phase and exploration and additionally for Exposure Day, Age, Sex. and Pairing have been calculated. The check helps assess the reliability of the model by identifying potential multicollinearity. In this case, no problematic multicollinearity among the predictors were found because the VIF values ranged from 1.0 – 1.8.

After the tests, a Generalized Linear Mixed Model (short: GLMM; Skrondal & Rabe - Hesketh, 2010) with a Gamma distribution is fitted using glmmTMB packages (Brocks et. al., 2025) with the following parameters:

The response variable is the log-transformed feeding duration, and the predictors are the phase and the personality type exploration. Fixed effects are included as well such as Age, Sex and Pairing status. Random effects such as the Bird ID accounts for repeated measures within individuals, ensuring that the results are not biased by individual differences (Schielzeth & Nakagawa, 2013). Additional random factors including Exposure Day (1-6), starting quadrant (sector) and Behavior instance were also incorporated into the model. The Behavior instance acts as observation-level random effects (OLRE) and function as a unique identifier for each behavior (Harrison, 2014). To identify potential issues in the model and see if the GLMM is reliable and valid, further tests have been conducted. The Residual Analysis testing the randomness in residuals, the Q-Q Plot observing the residual distribution and see whether they are normally distributed or not. Furthermore, the DHARMa Diagnostic has been assessed for the evaluation of the model fit (Hartig, 2020). Therefore, this includes the Dispersion test which detects overdispersion and ensures the correct modelling of the variance. No deviation from dispersion was detected, indicated by a significant p-value (dispersion = 0.99, p = 0.912). Secondly, the Uniformity Test verifies that the residuals are distributed in a uniform fashion and the Zero Inflation Test clarifies if the data contains more zeros than the model predicts and can subsequently impact the model structure (Hartig, 2020). The results revealed no significance, meaning no deviation from uniformity (p = 0.539). Finally, the outlier test showed a non-significant result as well (p = 0.95), indicating that no influential outliers were detected in the model.

The optimal fitted model (Supplementary Table 1), which successfully passed all diagnostic tests, examined the response variable duration in relation to the phase (before launch, exposure and after landing) and its interaction with exploration and the independent variable Age, while random effects accounted for BirdID (variance: 0.008, p = 0.094) and Behavior instance (variance: 0.031, p = 0.178).

6. Results

6.1 General results

The initial analysis of the experiment was conducted without considering the personality, focusing on the different behavioral responses across three phases: before launch, exposure phase and after landing (Supplementary Figure 6-13). These findings are consistent with the results of my colleague, who worked with the same dataset (Surlemont, 2025). Geese spent 17.51 % of their total before launch time feeding (Estimate: 0.39 ± 0.15, p = 0.001) and 15.99 % during the after landing phase (Estimate: 0.82 ± 0.12, p = < 0.001). In contrast, feeding behavior accounted for 7.27 % in the exposure phase. The general behavior percentage showed different response patterns. Overall, the geese spent approximately 40 % of the time foraging across these phases. The V1 short neck behavior was significantly lower in the before launch phase (Estimate: -0.18 ± 0.09, p = 0.047) with the geese spending 6.9% of the total before launch time in this behavior. No significant difference was found between the exposure and after landing phase (Estimate: -0.17 ± 0.10, p = 0.085), with 10.75% in total during the exposure and 4,19% in the after landing phase. The long neck posture (V2) showed no significance in the before launch phase (1.32% of total before launch time; Estimate: 0.39 ± 0.15, p = 0.001) and after landing (0,78%; Estimate: 0.39 ± 0.15, p = 0.001) compared to the exposure phase (3,40%). The V3 one-eye-up posture, significant decreased during the before launch phase (0,5%; Estimate: -0.54 ± 0.16, p = 0.033), but no significant change was observed after landing (0,41%; Estimate: 0.26 ± 0.30, p = 0.383). The flock spent 10.09% of the total exposure time in the V3 one-eye-up posture.

Standing and walking accounted for all observed physical activities (movement). Walking was significantly more frequent during the before launch (6.56% of the total time; Estimate: 0.17 ± 0.03, p = < 0.001), and after landing phase (5.98%; Estimate: 0.16 ± 0.04, p = < 0.001) compared to the exposure phase and the geese spent 19.56% of the total exposure time walking. Standing occurred less often during both pre-launch (Estimate: -0.34 ± 0.04, p = < 0.001) and post landing phases (Estimate: -0.24 ± 0.04, p = < 0.001), compared to the exposure phase. The geese spent 29.44% of their total before launch time standing, 23.00% of the exposure time and 19.56% of the total after landing phase in this behavior.

6.2 Foraging time budget

To assess whether exploratory behavior influences feeding durations, the exploration score was used to improve visualization and interpretation of the results. This classification was done by dividing the Delta Latency values into five bins -2, -1,0,1 and 2. Exploration scores were then assigned to see differences in feeding duration across the phases before launch, exposure phase and after landing (Figure 1). To test this, a Tukey-adjusted pairwise comparison was performed with all the scores to see whether there are significant variations between them within the specific phases. During the exposure phase no significant differences were found between any of the score (Table 2 ; Figure 5): Exploration Score -2 and -1 (Estimate: 0.05 ± 0.09, p = 0.974), Exploration Score -2 and 0 (Estimate: -0.07 ± 0.1, p = 0.951), Exploration Score -2 and 1 (Estimate: -0.03 ± 0.12, p = 0.998), Exploration Score -2 and 2 (Estimate: - 0.01 ± 0.10, p = 0.999), Exploration Score -1 and 0 (Estimate: -0.13 ± 0.09, p = 0.618), Exploration Score -1 and 1 (Estimate: -0.09 ± 0.11, p = 0.918), Exploration Score -1 and 2 (Estimate: -0.07 ± 0.09, p = 0.924), Exploration Score 0 and 1 (Estimate: 0.04 ± 0.12, p = 0.997), Exploration Score 0 and 2 (Estimate: 0.05 ± 0.1, p = 0.983) and Exploration Score 1 and 2 (Estimate: 0.01 ± 0.12, p = 0.999). Within the after landing period the exploration scores showed no differences given the following values (Table 3 ; Figure 6): Exploration Score -2 and -1 (Estimate: 0.03 ± 0.13, p = 0.999), Exploration Score -2 and 0 (Estimate: 0.31 ± 0.18, p = 0.397), Exploration Score -2 and 1 (Estimate: 0.03 ± 0.14, p = 0.999), Exploration Score -2 and 2 (Estimate: - 0.05 ± 0.14, p = 0.997), Exploration Score -1 and 0 (Estimate: -0.34 ± 0.18, p = 0.308), Exploration Score -1 and 1 (Estimate: 0.003 ± 0.14, p = 1.000), Exploration Score -1 and 2 (Estimate: -0.08 ± 0.14, p = 0.982), Exploration Score 0 and 1 (Estimate: 0.35 ± 0.18, p = 0.341), Exploration Score 0 and 2 (Estimate: 0.26 ± 0.19, p = 0.650) and Exploration Score 1 and 2 (Estimate: -0.08 ± 0.15, p = 0.982).

Only the before-launch phase showed a difference in feeding duration relative to the scores (Figure 2). Within the before launch phase, a trend was observed in the relationship to exploration scores and feeding duration, with a higher score associated with increased feeding duration. The pairwise comparison revealed a significant difference between Exploration Score -2 and 0 (Estimate: -0.38 ± 0.11, p = 0.009), indicating that the feeding duration differs significantly between these two exploration scores (Table 1). No significant differences were found between the following pairs: Exploration Score -2 and -1 (Estimate: -0.17 ± 0.08, p = 0.2982), Exploration Score -2 and 1 (Estimate: -0.24 ± 0.1, p = 0.1572), Exploration Score -2 and

2 (Estimate: 0.23 ± 0.09, p = 0.0987), Exploration Score -1 and 0 (Estimate: 0.21 ± 0.12, p = 0.4277), Exploration Score -1 and 1 (Estimate: -0.07 ± 0.11, p = 0.9672), Exploration Score -1 and 2 (Estimate: -0.06 ± 0.1, p = 0.9710), Exploration Score 0 and 1 (Estimate: 0.13 ± 0.13, p = 0.8534), Exploration Score 0 and 2 (Estimate: 0.14 ± 0.12, p = 0.7832) and Exploration Score 1 and 2 (Estimate: 0.008 ± 0.2, p = 1.0000).

Therefore, this comparison only revealed a significant difference between Exploration Score -2 and 0 (Table 1). For further investigation, the estimated marginal means (EMMs) were calculated for the most and the least exploratory geese. This analysis provided clearer understanding of the feeding duration differences between these two groups, leading to more robust results and significant findings (Figure 3). The comparison revealed a significant difference between the most and least exploratory geese showing that feeding duration increased with a higher tendency to explore (Estimate: -0.23 ± 0.06, p = 0.0060).

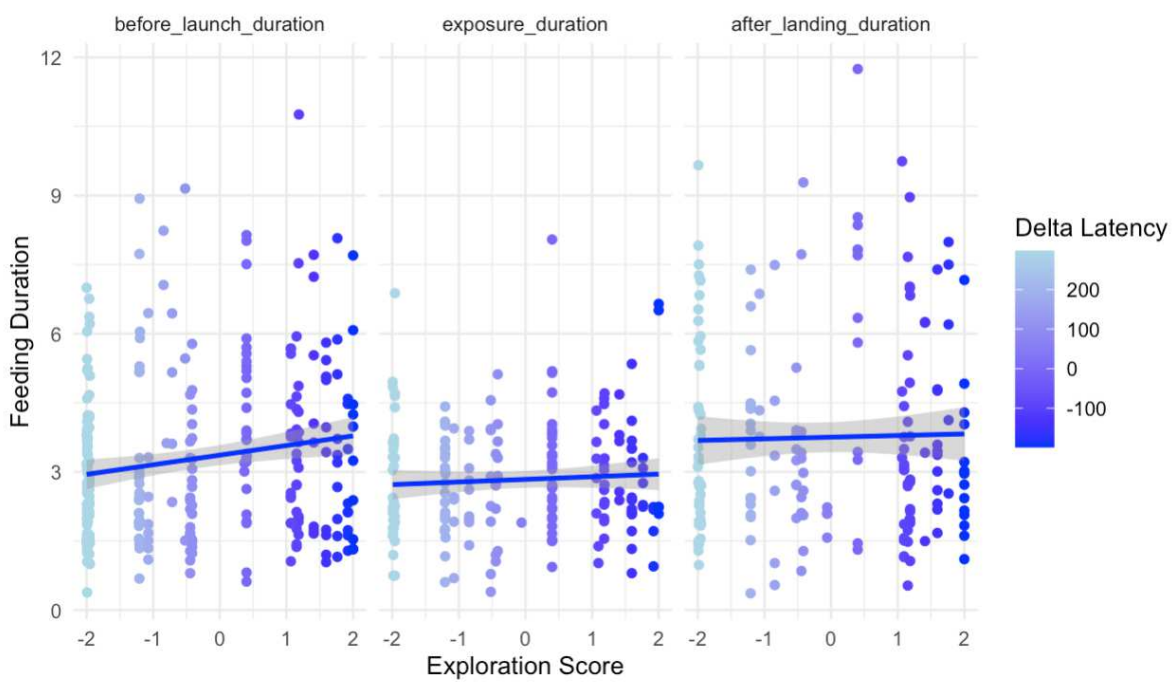


Figure 1: The feeding duration (seconds) across the three phases before launch, exposure phase and after landing in relation with the exploration score. The exploration score is divided into 5 bins (-2, -1, 0, 1, and 2), corresponding to a range of Delta Latency values from -300 to 300. A lower exploration score indicates higher Delta Latency values and a reduced tendency for exploratory behavior. “Before launch” defines the baseline phase without the artificial Predator (Robot Falcon), “Exposure phase”: Robot Falcon launches and hovers above the flock and the subsequent “After Landing Phase” describes the withdrawn and the landing time of the Falcon. In the before launch phase, there is a difference between exploration score in correlation to the feeding duration, suggesting higher exploratory individuals (score 2) to exhibit more feeding time.

Table 1: Tukey adjusted pairwise-comparison for the five different scores (-2,-1,0,1,2) during the "before launch phase" in correlation to the feeding duration (seconds). The exploration score -2 indicating a low tendency of exploratory behavior and an increase of the score leads to an increase of the willingness to explore. A significant difference is shown between the exploration score -2 and 0, indicating a lower feeding duration with a negative exploration score.

Estimate: describes an effect of a predictor variable, **Standard Error**: variability of the estimated coefficient, **z-value:** ratio of the estimate to the standard error, Pr (>|z|): **P-value** indicating significance

contrast	estimate	SE	z.ratio	p.value
Exploration score (-2) – Exploration score (-1)	-0.17	0.08	-1.93	0.298
Exploration score (-2) – Exploration score (0)	-0.38	0.11	-3.28	**0.009**
Exploration score (-2) – Exploration score (1)	-0.24	0.10	-2.26	0.157
Exploration score (-2) – Exploration score (2)	-0.23	0.09	-2.46	0.098
Exploration score (-1) – Exploration score (0)	-0.21	0.12	-1.71	0.427
Exploration score (-1) – Exploration score (1)	-0.07	0.11	-0.64	0.967
Exploration score (-1) – Exploration score (2)	-0.06	0.10	-0.62	0.971
Exploration score (0) – Exploration score (1)	0.13	0.13	1.00	0.853
Exploration score (0) – Exploration score (2)	0.14	0.12	1.14	0.783
Exploration score (1) – Exploration score (2)	0.008	0.12	0.06	1.000

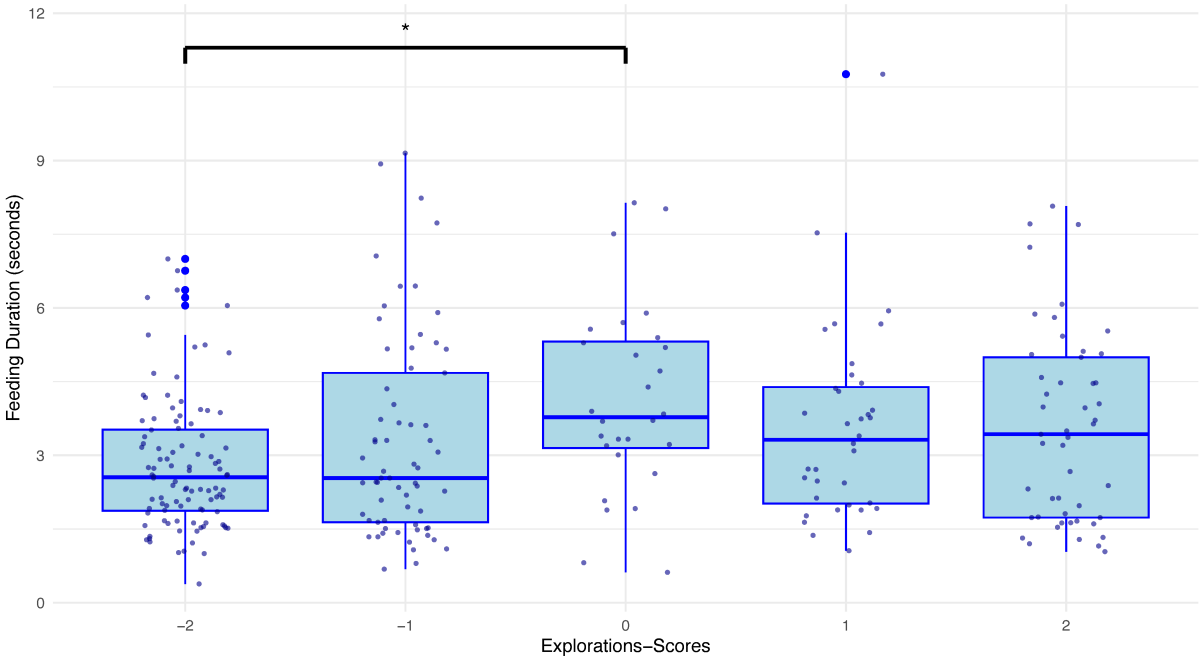


Figure 2: A Tukey-adjusted pairwise comparison for the exploration score divided into 5 bins (-2, -1, 0, 1 and 2) corresponding to a range of Delta Latency values from -300 to 300. The exploration score is plotted against the feeding duration (seconds) during the pre-launch phase to examine potential differences between the scores. The only significance was observed between the score -2 and 0, indicating a shorter feeding duration compared to those with a higher exploration score (Estimate: -0.38423, p = 0.009 **). The exploration score of -2 exhibited a lower feeding time budget compared to the score of 2, with the difference being marginally significant (Estimate: -0.23653, p = 0.098).

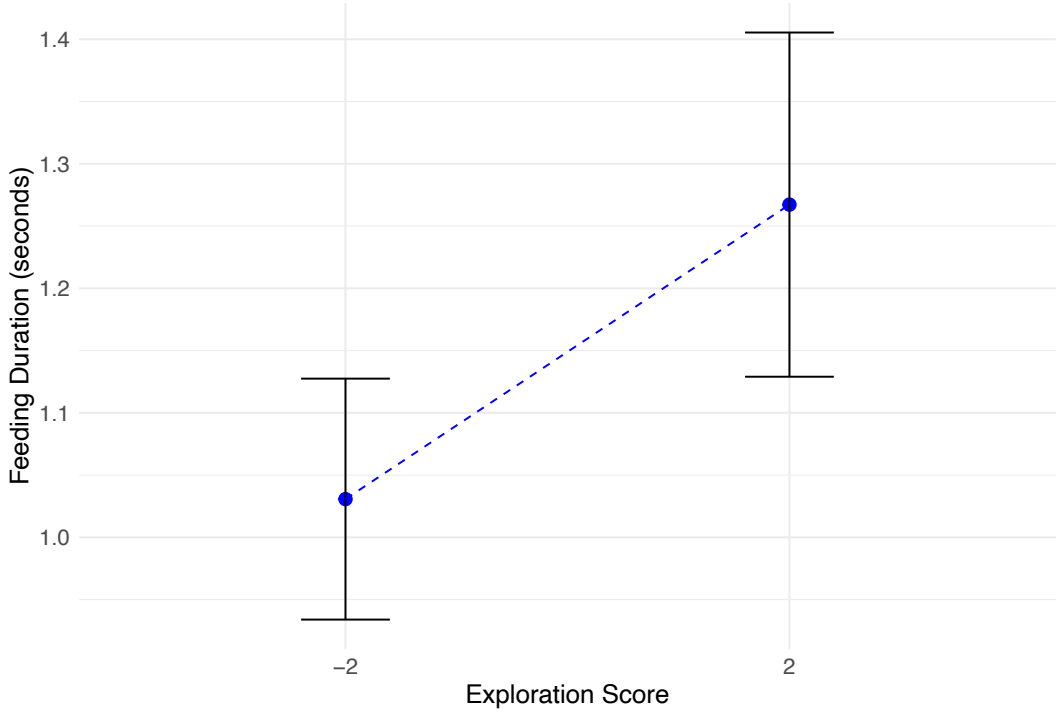


Figure 3: estimated marginal means (EMMs) of feeding duration for geese with extreme exploration scores (-2 and 2) during the before launch phase. There is a significant difference in feeding time with least exploratory geese (-2) spending less time feeding compared to the strong explorers (2). This difference is supported by the Tukey adjusted pairwise comparison, indicating that the feeding duration is significantly shorter for less exploratory geese (Estimate: -0.237, p = 0.006). The points represent the average feeding duration, and the error bars indicate 95% confidence interval.

6.3 Tradeoff between vigilance and feeding

Vigilance and feeding behavior were analyzed to assess whether a trade-off exists between these two responses (Figure 4). Vigilance consists of three behavioral responses, namely short-neck (V1), long neck (V2) and one eye up (V3) and are grouped together. They have been tested separately using the gamma GLMM function, assessing if the vigilance responses differ across phases and if the personality influences the alertness states. The exploratory personality does not seem to have an influence on the alertness states ($\chi^2 = 6.88$, $p = 0.141$). Importantly, the overall vigilance duration, including all of the three behavioral responses, was found to be higher during exposure compared to the after-landing phase (Estimate: -0.28 ± 0.10, p = 0.007 **), while no significant difference was observed when comparing the exposure phase to the before launch phase (Estimate: -0.12 ± 0.09, p = 0.194), as shown in Table 7.

Finally, the overall vigilance duration is higher during exposure and the feeding time budget simultaneously decreases, suggesting that a trade-off between vigilance and foraging is given. Personality seems to have an influence on the feeding time budget but not on the vigilance responses irrespective of the phase. The comparison between vigilance and feeding duration reveals a clear trade-off between foraging and alertness across the three phases (before launch, exposure and after landing phase), as highlighted in Figure 5. Before the Robot Falcon hovered above the flock, feeding behavior dominated across all exploration score categories. Individuals with an exploration score of 2 spent approximately 85,5 % of their time feeding and 14,5 % being vigilant. Those with a score 1 showed 83 % feeding and 17 % vigilance, while score 0 individuals spent 81 % of the time feeding and 19 % on vigilance. Geese with a score of -1 fed 90 % and were 10 % of the time in a vigilant state Those with a score of -2 spent 84% grasping and 16% in an altered state. During the exposure of the artificial falcon, the feeding behavior markedly decreased while vigilance increased across all exploration score categories. Individuals with a score of 1 and 0 both spent 35 % of their time feeding and 65 % engaged in vigilance. Those with a score of -1 showed slightly more foraging (40%) and 60 % vigilance. The most pronounced shift was observed with individuals with a score of -2, who spent only 25% of the time feeding and 75 % displaying vigilance behavior. Only individuals with an exploration score of 2 showed an even distribution, spending 50 % of their time feeding and 50 % being vigilant. After the artificial predator had landed, the behavior of the geese shifted with a clear increase in feeding activity and a reduction in vigilance. Individuals with a score of

2 returned to approximately 85,5 % feeding and 14,5 % vigilance. Those with score 1 and 0 showed a similar pattern, each spending 90 % of their time foraging and only 10 %being vigilant. Score -1 individuals fed 86 % of the time and showed vigilance for 14 %, while geese with a score of -2 individuals spent 83 % of the time feeding and 17 % being alert (Table 8).

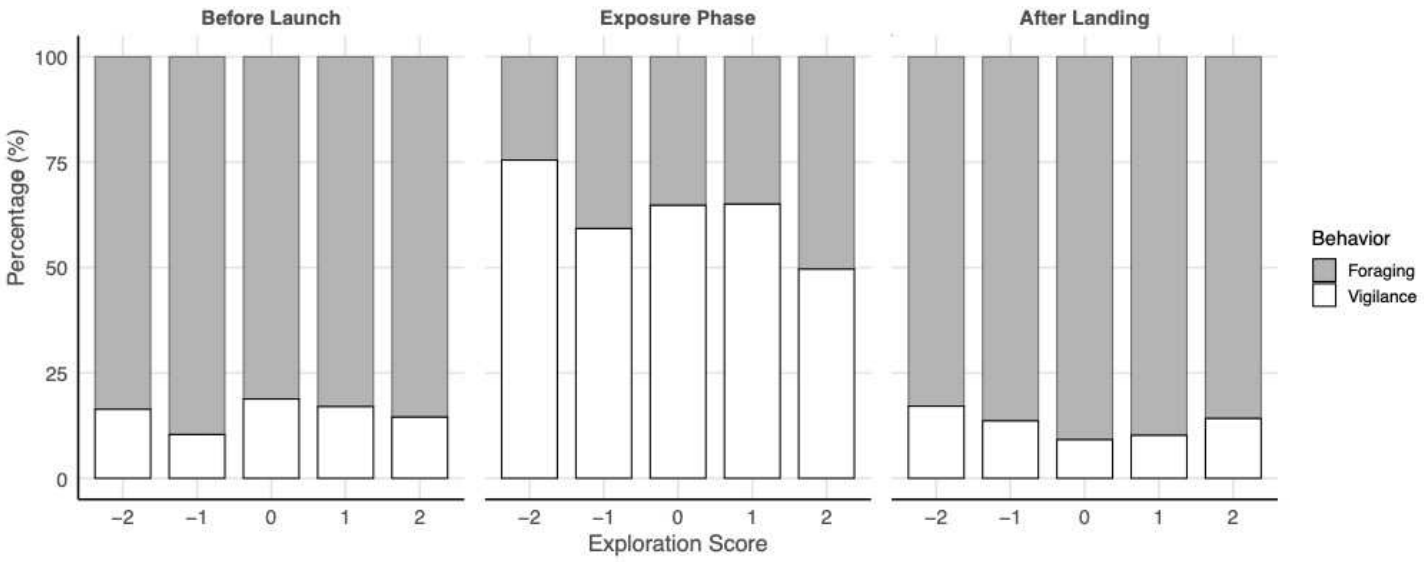


Figure 4: The normalized percentage of two behavioral responses: non vigilant feeding behavior (V0) compared to the vigilance response (including short neck V1, long neck V2 and one-eye up V3). “Before launch” defines the baseline phase without the artificial Predator (Robot Falcon),” Exposure phase”: Robot Falcon launches and hovers above the flock and the subsequent “After Landing Phase” describes the withdrawn and the landing time of the Falcon. This graph shows the difference in the behavioral duration across phases and exploration scores (-2,-1,0,1,2), highlighting the tradeoff between vigilance and foraging. As feeding duration increases, there is a simultaneous decrease in vigilance response, and vice versa.

7. Discussion

This study investigated individual variation in exploration in terms of food neophobia and its effect on foraging behavior in greylag geese (*Anser anser*) under simulated predation risk. The results confirm that the experimental design reliably elicited behavioral changes: geese consistently reduced feeding and increased vigilance during predator exposure, validating the setup as an effective threat simulation. Critically, the findings suggest that more exploratory individuals spent more time feeding, but only in the absence of an immediate threat – before predator exposure. During and after the exposure phase, this personality effect disappeared, suggesting that predator presence overrides individual differences in exploratory behavior. These findings highlight that while exploration influences feeding under low-risk conditions, its effect is context-dependent and suppressed under acute predation risk. This supports the idea that personality traits such as neophobia shape behavior in specific ecological contexts but may be constrained by overriding survival priorities.

This study aimed to test whether individual variation in exploration, a trait often associated with food neophobia, predicts foraging behavior under varying predation risk. It is important to distinguish between the constructs of general neophobia, food neophobia and exploration. While these traits often appear to overlap, they are not identical and are assessed using different experimental approaches. Exploration involves the investigation of novel situations or items (Takola et. al., 2021), while general neophobia specifically characterizes the individual's caution in engaging with novel stimuli (Sih et. al., 2023). General risk sensitivity, by contrast, reflects a behavioral mechanism of an individuals' willingness to take risk regardless of whether stimuli are novel or familiar (Houston & Rösenstrom, 2024). In this study, food neophobia was operationalized using Delta Latency values, quantifying the time animals take to approach a food source with a novel object present (Kleindorfer et. al., 2024b). Distinguishing between general risk avoidance and food neophobia helps clarify the difference between avoiding novelty and general risk-taking behavior, with variations observed across species showing individual differences based on their life history strategies, ecological context and cognitive abilities (Greenberg, 2012; Wolf et. al., 2007). Focusing on neophobia in relation to exploratory tendencies, specifically in the presence of a novel object, allows for an examination of how these traits influence the feeding time budget. By using Delta latency

values, individuals were categorized along an exploration spectrum from weak to strong explorers, enabling the investigation of individual variation in feeding behavior. Ecologically, this trait is important because it reflects an individual's disposition to be either fearful or fearless towards the unknown, influencing the ability to gather information and behavioral adaptation to environmental changes. This, in turn, helps to understand how exploration can vary in their likelihood to explore novelty (Greggor et. al., 2015). Previous neophobia test have shown high repeatability (Takola et. al., 2021) across different context, but no significant correlation between them (Kleindorfer et. al., 2024b; Common et. al., 2024). Risk taking appetite seem to not be predictive of the response in different contexts of risk. This may be due to the fact that exploration was measured solely in the context of feeding. The controlled feeding regimen of the geese in Grünau im Almtal, receiving food twice daily without dietary restrictions, may have influenced the absence of a correlation in the results. This approach frames exploration within the context of the time budget but does not connect it to feeding diversity (GarcÍa-Loor, 2025), which could a contributing factor to the absence of a connection between exploration and vigilance. Additionally, exploration was assessed in a familiar and restricted habitat in Grünau im Almtal, Upper Austria. Implementing a novel-environment test, where geese are introduced to unfamiliar habitats, could provide another approach of exploration in response to new habitat and potential novel threats and situations (Huang et.al., 2016; Jones & Godin, 2010; Carere et.al., 2005). This approach may reveal deeper insights into the behavioral ecology of the geese, particularly how exploration varies in a new setting and whether it influences vigilance responses.

Understanding how exploration is measured across context is essential, as differences in test design can influence whether findings generalize or reflect context specific behavior. Across studies, exploration can be measured through various approaches. As mentioned above, exposing individuals into a novel habitat rather than a novel object (Huang et. al., 2016) can reveal differences in exploratory behavior in relation to a novel place rather than a feeding context. This may imply a variation in behavioral responses depended on the stimuli. Alternatively, O'Hara et.al (2017) introduced the concept of "neotic style" across different bird species, treating neophobia and exploration as independent variables (O'Hara et.al., 2017). This approach could lead to different results, because treating them separately may reveal how each trait independently influences foraging behavior. Separating these traits may offer

insights into distinct behavioral strategies, for example, an individual might be quick to explore a novel environment but still cautious around unfamiliar food. Hence, the use of different classifications and experimental set-up may influence the variation in behavior across different contexts. For instance, categorizing exploratory behavior into “fast” and “slow” explorers based on both a novel environment and object test could provide a more comprehensive measure of exploration by capturing responses to novelty across both habitat - and object related contexts (Carere et. al., 2005; Nácarová et.al., 2018). Moreover, the social environment can also impact exploratory behavior, as shown in a study on common ravens (*Corvus corax*), where the presence of a conspecific can influence an individual’s willingness to explore. In the presence of a kin, social facilitation can reduce fear towards novelty, highlighting the role of social context in shaping exploratory tendencies (Stöwe et.al., 2006b).

Finally, it could be beneficial to adopt different methodological approach and additionally incorporate variables such as social constellations and proximity to mate. Further investigations could explore whether certain behaviors are partner specific, observing functionally equivalent or complimentary behavior combinations (Scheiber et.al., 2013). Paired geese act synchronously (functionally equivalent) or exhibit different behavioral responses (complimentary), for example the male feeds while the female remains vigilant (Scheiber et. al., 2013) or vice versa (Dick, 1988). Considering these dynamics could shift the focus and provide deeper insights into vigilance and feeding behavior across different social configurations, such as pairs, single or trios, which may in turn influence the feeding time budget in relation to partner presence.

The context dependency of exploratory behavior in feeding scenarios underscore how individual variation in exploration can shape the amount of foraging in response to perceived threat. In this study, strong explorers (exploration score 2) tend to spend more time feeding during the before launch phase, indicating that they are less neophobic and cautious. This observation aligns with findings of Verbeek et.al’s on great tits (*Parus major*; 1994), where slow explorers exhibited longer latencies when approaching a novel object. Consequently, it is plausible strong explorers have a larger feeding time budget, likely driven by reduced neophobia and greater propensity for exploration (Verbeek et.al., 1994). Reconsidering exploration within a feeding context reveals that feeding duration primarily reflects the current energetic needs relative to immediate risk (Lima & Dill, 1990). In contrast, the neophobia threshold hypothesis proposes that individuals differ in their baseline sensitivity to

novelty, which influences their exploratory and foraging decisions. More exploratory geese tend to have a broader foraging repertoire and higher foraging diversity, with exploration linked to foraging behavior (GarcÍa-Loor, 2025; Forss et. al., 2017). However, considering exploration from a time-budget standpoint, it offers a different lens and provides additional insights into how this personality trait influences the duration of food acquisition rather than focusing on its diversity. These varying perspectives underscore the importance of considering different contexts and influencing factors when analyzing exploratory behavior. Consequently, factors such as flock size and social structure, as well as and ecological aspects like predation risk and resource availability can influence the extent of exploratory behavior, varying not only between species but also among individuals across different situations (Miller et.al., 2022). Social factors such as flock size could influence behavioral responses (Lima, 1995), for instance, larger groups size is often associated with reduced individual vigilance allowing more time for activities like foraging (Zaynagutdinova et.al., 2020). In this study, only 61 recording were conducted, of which 55 were included due to the available life history information of the geese. A limited dataset can reduce the statistical power and making it more difficult to generalize the findings and may affect the overall strength of the conclusion from the data in this experiment (Mathur et. al, 2014). Additionally, during the presentation of a threat, a phenomenon known as “phase transition” may play a role, as individuals tend to cluster into a V-shaped formation and personality appears to have no influence (Kleindorfer, 2024a). Furthermore, incorporating dominance status could offer deeper insights into social hierarchies and their potential impact on exploratory behavior. Some studies have reported a link between dominance and exploration (e.g. Arctic barnacle geese, *Branta leucopsis*; Stahl et. al., 2001, great tits, *Parus major*; Dingemanse & de Goede, 2004, parrots, *Psittaciformes*; Mettke-Hoffmann, 2012) which have identified the potential correlation between these behavioral characteristics. Thus, including dominance status could be a valuable direction to determine whether exploration is influenced by this social variable. Furthermore, considering stress levels, physiological changes and heart rate could improve the evaluation of individual responses (Kralj-Fišer et. al., 2009). When observing paired individuals, this could provide insights whether the geese experience stress due to the perceived threat or because their partner is not nearby. By assessing heart rate and stress levels, it would be possible to determine whether any increase in these factors is driven by social stress (absence of partner, agonistic interaction etc.) or by the presence of the predator. This would help to confirm that

the observed vigilance responses are solely due to the predator threat and not influenced by the social context. Lastly, the absence of family constellation and goslings may have influenced the results, with parents with goslings altering their behavioral responses during predator exposure (Szipl et.al., 2019; Forslund, 1993), for example males tending to be more vigilant and reduce foraging time, as seen in Pink footed geese (*Anser brachyrhynchus*) (Lazarus & Inglis, 1978). Thus, the absence of parental may partially skew the results.

Reconsidering the findings of this study, the increased feeding time observed in more exploratory individuals could be driven by several underlying factors, such as differing risk-taking abilities. More exploratory individuals may have a higher willingness to investigate novel objects or habitats and may be less threatened by potential risks (Pisula & Modlinska, 2023). This behavioral inclination may reflect a trade–off: an increase in feeding leads to a higher energy benefit but simultaneously may elevate the risk of predation, especially in unfamiliar habitats where knowledge about feeding site is limited (Wolf et. al., 2007; Lima & Dill, 1990). In species such as great tits (*Parus major,* Van Oers et.al., 2004) and zebra finches (*Taeniopygia guttata*, Martins et. al., 2007), exploratory behavior correlates with risk taking, and a higher tendency may result in greater foraging activity (Van Oers et.al., 2004). This could emphasize the assumption that a higher exploration score is linked with a greater foraging time. The species differences in personality traits highlight the crucial role of social and ecological factors in shaping the expression of these behaviors (Quinn et. al., 2012; Dingemanse & Réale, 2005). The adaptive value of increased exploratory behavior may be influenced by ecological differences like predator abundance and environmental conditions as well as different foraging strategies and ecology which lead to varying foraging efficiencies (Winkler & Leisler, 1999; Tebbich et. al., 2010). Thus, exploration does not necessarily lead to higher foraging efficiency, as its benefits may be constrained by the individual neophobia, and this can restrict the interaction with unfamiliar resources (Greenberg, 2012). To gain more insights, incorporating additional factors like foraging efficiency rather than just feeding duration, would help quantify the effectiveness of foraging under predator exposure conditions and see whether vigilance affects not only the time spent feeding but also the effectiveness of foraging in relation to a potential threat. This could answer the question whether feeding time is directly related to effective energy intake or if individuals with a higher exploration score are facing higher costs of risk. Furthermore, another possible future method would be to measure the latency to reach a specific feeding tray in the experiment. Specifically, the set-up could be adjusted to

evaluate the difference between the baseline latency and the latency to reach the food tray in the presence of a predator. This could help determine whether the probability of accessing a food source changes under increased predation risk and if predator neophobia affect the feeding time budget.

Surprisingly, the association between feeding time budget and personality, observed in the before-launch phase, seems to disappear in the subsequent phases (exposure and after landing). The overshadowing high-risk condition prioritize an alertness response over a personality shaped effect. A plausible explanation could be a "carry-over effect" of predator exposure, where heightened vigilance responses override pre-existing feeding differences during exposure (Abbey-Lee et.al., 2016, Harrison et.al., 2011; Harris et.al., 2020). This effect may carry over into the after-landing phase, where no significant differences in individual exploration tendencies are found, suggesting that predator's presence induces lingering behavioral shift and altered feeding durations. Bearing this in mind, in a threatening situation, the immediate perception of risks likely outweighs exploratory tendencies in determining vigilance. The starvation-predation risk trade-off hypothesis' may support this prediction, proposing that foraging decisions are shaped by the immediate level of risk (Bonter et. al., 2013; Lima & Dill, 1990; Watson et. al., 2007). While exploration influence how geese interact with a food source under low-risk conditions, during exposure of a predator, vigilance may be driven by the perceived threat rather than by an individuals' exploratory behavior. This suggests that exploration has less of an impact on vigilance when the immediate need for threat detection overrides other behavioral tendencies. This aligns with the idea that under predation pressure behavioral responses become flexible and adaptive to immediate environmental stimuli, which can temporarily prevail over stable personality traits (Bell & Sih, 2007).

Finally, considering the environmental and ecological influences are essential to understand the complexity of behavioral responses under a given experimental set-up. Nonetheless, a few factors may have influenced the results and should be mentioned. Habituation, a reduced response to repeated stimuli (Dong & Clayton, 2009), may have occurred nonetheless as the geese became familiar with the experimental setting and displayed diminished response (Storms et.al., 2022). Additionally, the short frequency of exposure sessions and the short

length of the experiment (n = 8 days) limited the ability to assess long-term effects on greylag geese and their broader behavioral responses to the falcon over an extended period. Moreover, the presence of humans in this habitat is a regular occurrence for the geese, as they are accustomed to receiving food from humans daily, leading to a diminished stress response to non-threatening disturbances over time (Gruber et. al., 2019; Müller et. al., 2014). These factors may have influenced both feeding and vigilance behaviors during the experiment. Future studies should address these limitations by extending the length of the experiment to minimize habituation effects and reduce human presence to further enhance the strength of the results.

7.1 Conclusion

As expected, all individuals showed increased vigilance and reduced feeding during the exposure phase, confirming that the predator simulation effectively induced a threat response. However, this effect appeared independent of individual exploratory tendencies, supporting the idea that general vigilance behavior is driven primarily by perceived risk, not personality. Therefore, the focus specifically lays on how food neophobia influenced feeding behavior during predator exposure.

This study reveales that exploration has an impact on the feeding time budget of greylag geese (*Anser anser*), with more exploratory individuals spending more time foraging, particularly in the pre-launch phase. This suggests that geese with lower food neophobia may exploit available resources more readily under low-risk conditions. However, this effect was context-dependent: during the predator exposure and post-exposure phase, no significant differences in foraging time were observed across personality types. This indicates that the presence of a threat overrides the influence of personality traits such as exploration, likely due to an increased emphasis on vigilance as a survival response. It remains unclear whether the absence of exploratory variation during and after exposure is due to a carry-over effect of perceived threat, or if other ecological, social, or environmental factors modulate these responses.

Overall, this study highlights that the effect of food neophobia on foraging is phase-specific and susceptible to contextual influences such as predation risk. The results underscore the need to consider both intrinsic traits and extrinsic factors when interpreting behavioral variation. Incorporating additional parameters, such as social hierarchy, group size, foraging efficiency or physiological state, may further clarify the mechanisms shaping individual responses under varying ecological pressures.

8. Literature

Abbey-Lee R. N., Kaiser A., Mouchet A., & Dingemanse N. J. (2016). Immediate and carry-over effects of perceived predation risk on communication behavior in wild birds*. Behavioral Ecology*, *27*(3), 708–716. https://doi.org/10.1093/beheco/arv210

Abdi, H., & Williams, L. J. (2010). Tukey's Honestly Significant Difference (HSD) Test. In N. Salkind (ed.), *Encyclopedia Research Design. Sage Publication*. https://personal.utdallas.edu/~herve/abdi-HSD2010-pretty.pdf

Ahrndt, S., & Albayrak, S. (2017). Learning about human personalities. In J. Berndt, P. Petta, & R. Unland (Eds.)*, Multiagent system technologies, MATES 2017* (Lecture Notes in Computer Science, Vol. 10413, pp. 3-15). Springer. https://doi.org/10.1007/978-3-319-64798-2_1

Barnas, A., Newman, R., Felege, C. J., Corcoran, M. P., Hervey, S. D, Stechmann, T. J., Rockwell, R. F., & Ellis-Felege, S. N. (2018). Evaluating behavioral responses of nesting lesser snow geese unmanned aircrafts surveys. *Ecology and Evolution, 8*(2), 1328-1338. https://doi.org/10.1002/ece3.3731

Bell, A. M., & Sih, A. (2007). Exposure to predation generates personality in threespined sticklebacks (*Gasterosteus aculeatus*). *Ecology Letters, 10*(9), 828-834. https://doi.org/10.1111/j.1461-0248.2007.01081.x

Bonter, D. N., Zuckerberg, B. Sedgwick, C. W., & Hochachka, W. M. (2013). Daily foraging patterns in free living-birds: Exploring the predation–starvation trade off. *Proceeding of the Royal Society B: Biological Sciences, 280*(1750), 20123087. https://doi.org/10.1098/rspb.2012.3087

Brocks, M., Bolker, B., & Kristensen, K. (2025). *glmmTB: Generealized linear mixed model using Template Model Builder*. https://cran.r-project.org/web/packages/glmmTMB/glmmTMB.pdf

Bulens, A., Sterken, H., Van Beirendonck, S., Van Thielen J., & Driessen B. (2015). The use of different objects during a novel object test in stabled horses. *Journal of Veterinary Behavior, 10* (1), 54-58. https://doi.org/10.1016/j.jveb.2014.09.002

Cabrera, D., Nilson, J. R., & Griffen, B. D. (2021). The development of animal personality across ontogeny, A cross-species review. *Animal Behavior, 173,* 137-144. https://doi.org/10.1016/j.anbehav.2021.01.003

Carere, C., Drent, P. J, Privitera, L., Koolhaas, J. M., & Groothuis, T. G. G. (2005). Personalities in great tits (*Parus major*): Stability and consistency. *Animal Behaviour, 70*(4), 795-805. https://doi.org/10.1016/j.anbehav.2005.01.003

Common, K. L. (2024). Preliminary data on exploratory personality based on the novel object test, conducted at KLF research center

Common, L. K., Katsis, A. C., Frigerio, D. & Kleindorfer, S. (2024). Effects of assortative mating for personality on reproductive success in greylag geese, *Anser anser. Animal Behaviour, 216*, 141-153. https://doi.org/10.1016/j.anbehav.2024.08.004

Crane, A. L. & Ferrari Maud, C. O. (2017). Patterns of predator neophobia: a meta-analytic review, *Proceedings of the Royal Society B, 284*, 20170583. https://doi.org/10.1098/rspb.2017.0583

Dalmau, A., Fabregam, E., & Velarde, A. (2009). Fear assessment in pigs exposed to a novel object test. *Applies Animal Behavior Science, 117*(3-4), 173-180. https://doi.org/10.1016/j.applanim.2008.12.014

Dick, G. (1988). Feeding behavior of the Greylag Goose (*Anser anser*): a field study. *In Ecology of Birds, 10*, 59-69. Institute of Zoology, University of Vienna and Institute for Eco-Ethology, Rosenburg. https://www.zobodat.at/pdf/Oekologie-Voegel_10_0059-0070.pdf

Dingemanse, N. J., & de Goede, P. (2004). The relation between dominance and exploratory behavior is context dependent in wild great tits. *Behavioral Ecology, 15*(6), 1023-1030. https://doi.org/10.1093/beheco/arh115

Dingemanse, N. J., & Réale, D. (2005). Natural selection and animal personality. *Behavior, 142*(9-10), 1159-1184. https://doi.org/10.1163/156853905774539445

Dong, S. & Clayton, D.F (2009). Habituation in songbirds. *Neurobiology of Learning and Memory, 92* (2), 183-188. https://doi.org/10.1016/j.nlm.2008.09.009

Drezner, Z., Drezner, T. D., & Mihaylo, S. G. (2016). Emerging technologies: A remedy for the overzealous Bonferroni technique for multiple statistical tests. *Bulletin of the Ecological Society of America, 97*(1), 98. https://esajournals.onlinelibrary.wiley.com/doi/epdf/10.1002/bes2.1214

Fernandez-Juricic, E. (2012). Sensory basis of vigilance behavior in birds: Synthesis and future prospects. *Behavioural Processes, 89,* 143-152. https://doi.org/10.1016/j.beproc.2011.10.006

Forslund, P. (1993). Vigilance in relation to brood size and predator abundance in the barnacle goose, *Branta leucopsis*. *Animal Behavior, 45* (5), 965 – 973. https://doi.org/10.1006/anbe.1993.1115

Forss, S. I. F., Koski, S. E. & van Schaik, C. P. (2017). Explaining the paradox of neophobic explorers: The social information hypothesis. *International Journal of Primatoloy, 38,* 799–822. https://doi.org/10.1007/s10764-017-9984-7

GarcÍa–Loor, J. (2025). Exploration behavior is repeatable and associated with foraging behavior in Island Songbirds. University of Vienna. https://phaidra.univie.ac.at/detail/o:2117463

Gastwirth, J. L., Gel, Y. R., & Miao, W. (2009). The impact of Levene's test of equality of variances on statistical theory and practice. *Statistical Science, 24*(3), 343–360. https://doi.org/10.1214/09-STS301

Greenberg, R. (2012). The role of neophobia and neophilia in the development of innovative behavior of birds. In S. M. Reader & K. N. Laland (Eds.), *Animal Innovation* (pp. 175–196), Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198526223.003.0008

Greggor, A. L., Thornton, A., & Clayton, N. S. (2015). Neophobia is not only avoidance: Improving neophobia tests by combining cognition and ecology. *Current Opinion in Behavioral Science, 6*, 82-89. https://doi.org/10.1016/j.cobeha.2015.10.007

Gruber, T., Luncz, L., Mörchen, J., Schuppli, C., Kendal, R., & Hockings, K. (2019). Cultural change in animals: A flexible behavioural adaptation to human disturbance*. Palgrave Communications, 5*, 64. https://doi.org/10.1057/s41599-019-0271-4

Harrison X. A. (2014). Using observation-level random effects to model overdispersion in count data in ecology and evolution. *PeerJ, 2,* e616. https://doi.org/10.7717/peerj.616

Harrison, X. A., Blount, J. D., Inger, R., Norris, D. R. & Bearhop, S. (2011). Carry-over effects as drivers of fitness differences in animals. *Journal of Animal Ecology, 80*, 4-18. https://doi.org/10.1111/j.1365-2656.2010.01740.x

Harris, S. M. Descamps, S., Sneddon, L. U., Cairo, M., Bertrand P., & Patrick, S. C. (2020). Personality-specific carry over effects on breeding. *Proceeding of the Royal Society B: Biological Sciences, 287*(1934), 20202381. https://doi.org/10.1098/rspb.2020.2381

Hartig, F. (2020). *DHARMa: Residuals diagnostics for hierarchical (multi-level/mixed) regression models,* R package version 0.3.3.0, Available at CRAN, https://cran.r-project.org/web/packages/DHARMa/vignettes/DHARMa.html

Houston, A. I. & Rösenstrom, T. H. (2024). A critical review of risk-sensitive foraging. *Biological Reviews, 99*(1), 478-495. https://doi.org/10.1111/brv.13031

Huang, P., Kerman, K., Sieving, K.E. & St. Mary, C. M. (2016). Evaluating the novel-environment test for measurement of exploration by bird species. *Journal of Ethology, 34*, 45–51. https://doi.org/10.1007/s10164-015-0444-6

Ihaka, R., & Gentleman, R. (1996). R: A language for data analysis and graphics*, Journal of Computational and Graphical Statistics*, *5*(3), 299-314. https://www.stat.auckland.ac.nz/~ihaka/downloads/R-paper.pdf

Jablonszky, M., Krenhardt, K., Markó, G., Szász, E., Hegyi, G., Herenyi, M., Kötél, D., Laczi, M., Nagy, G., Rosivall, B., Török, J., & Garamszegi, L. Z. (2020). A behavioural trait displayed in an artificial novel environment correlates with dispersal in a wild bird. *Ethology, 126*(5), 540-552. https://doi.org/10.1111/eth.13005

Jones, K. A., & Godin, J. G. J. (2010). Are fast explorers slow reactors? Linking personality type and anti-predator behavior*. Proceedings of the royal society B: Biological Science, 277*(1681), 625-632. https://doi.org/10.1098/rspb.2009.1607

Kabacoff, R. I. (2015). *R in Action: data analysis and graphics with R* (2nd ed.). Manning Publications Co. https://www.cs.uni.edu/~jacobson/4772/week11/R_in_Action.pdf

Kaiser, M. I., & Müller, C. (2021). What is animal personality?. *Biology and Physiology, 36*(1), 1-27. https://doi.org/10.1007/s10539-020-09776-w

Kralj-Fišer, S., Scheiber, I. B. R., Blejec, A., Moestl, E., & Kotschral, K. (2007). Individualities in a flock of free- roaming greylag geese: Behavioral and physiological consistency over time and across situations. *Hormones and Behavior, 51*(2), 239-248. https://doi.org/10.1016/j.yhbeh.2006.10.006

Kralj-Fišer, S., Weiß, B. M., & Kotrschal, K. (2009). Behavioural and physiological correlates of personality in greylag geese (*Anser anser*). *Journal of Ethology, 27*(1), 37-45. https://doi.org/10.1007/s10164-009-0197-1

Kavaliers, M., & Choleris, E., (2001). Antipredator responses and defensive behavior: ecological and ethological approaches for the neurosciences*. Neuroscience and Biobehavioral Review, 25*(6), 577-586. https://doi.org/10.1016/S0149-7634(01)00042-2

Kleindorfer, S. (2024a). *Die erstaunliche Welt der Graugänse: Wie sie leben, kommunizieren und füreinander sorgen,* Brandstätter Verlag

Kleindorfer, S., Katsis, A. C., Frigerio, D., Lesigang, J., Mostafa, D., & Common, L. K. (2024b). Personality predicts collective behavior in greylag geese: Influencers are bold and followers are exploratory*. Konrad Lorenz Research Center for Behavior and Cognition, University of Vienna*. https://phaidra.univie.ac.at/detail/o:2072004

Kleindorfer, S., Krupka, M. A., Katsis, A. C., Frigerio, D., & Common, L. K. (2024c). Aggressiveness predicts dominance rank in greylag geese: Mirror test and agonistic interactions*. Royal Society Open Science, 11*, 231686. https://doi.org/10.1098/rsos.231686

Kluen, E., Rönkä, K., & Thorogood, R. (2022). Prior experience of captivity affects behavioural responses to 'novel' environments. *PeerJ, 10,* e13905. https://doi.org/10.7717/peerj.13905

Kotrschal, K., Hemetsberger, J., & Dittami, J. (1992). Vigilance in a flock of semi-tame greylag geese *Anser anser* in response to approaching eagles *Haliaeetus albicilla* and *Aquila chrysaetos*. *Wildfowl, 43,* 215-219. https://wildfowl.wwt.org.uk/index.php/wildfowl/article/viewFile/903/903

Lazarus, J., & Inglis, I. R. (1978). The Breeding behaviour of the Pink-Footed Goose: Parental care and vigilant behaviour during the fledging period*. Behaviour*, *65*(1-2), 62-87. https://doi.org/10.1163/156853978X00198

Lenth, R. V. (2023). *emmeans: Estimated marginal means, aka least-squares means* (R package version 1.8.9). https://cran.r-project.org/web/packages/emmeans/index.html

Lima, S. L. (1995). Back to the basics of anti-predator vigilance: The group-size effect. *Animal Behavior, 49*(1), 11-20. https://doi.org/10.1016/0003-3472(95)80149-9

Lima, S. L., & Dill, L. M. (1990). Behavioral decisions made under risk of predation–a review and prospectus. *Canadian Journal of Zoology, 68*, 619-640. https://doi.org/10.1139/z90-092

Lorenz, K. (1988). *Hier bin ich – Wo bist du?,* Ethologie der Graugans. Piper.

Martins T. L. F., Roberts, M. L., Giblin, I., Huxham, R., & Evans, M. R. (2007). Speed of exploration and risk-taking linked to corticosterone titres in zebra finches. *Hormones and Behaviors, 52*(4), 445-453. https://doi.org/10.1016/j.yhbeh.2007.06.007

Mathur, P., Pawar, P., & Rani, S. (2014). Sample size determination: A review. *Journal of Indian Association of Pediatric Surgeons, 19*(3), https://doi.org/10.1590/2176-9451.19.4.027-029.ebo

Mettke-Hofmann, C. (2012). Head colour and age relate to personality in Gouldian finches. *Ethology, 118*(10), 906-916. https://doi.org/10.1111/j.1439-0310.2012.02079.x

Miller, R., Lambert, M. L:, Frohnwieder, A., Brecht, K. F., Bugnyar, T., Cramptom , I., Garcia – Pelegrin, E., Gould, K., Greggor, A. L., Izawa, E-I., Kelly, D. M., Li, Z., Luo, Y., Luong, L. B., Massen, J. J. M., Nieder, A., Reber, S. A., Schiestl, M., Seguchi, A., Sepehri, P., Stevens, J. R., Taylor, A. H., Wang, L., Wolff, L. M., Zhang, Y., & Clayton, N. S. (2022). Socio-ecological correlates of neophobia in corvids. *Current Biology, 32*(1), 74-85e4, https://doi.org/10.1016/j.cub.2021.10.045

Moretti, L., Hentrup, M., Kotrschal, K., & Range, F. (2015). The influence of relationships on neophobia and exploration in wolves and dogs. *Animal Behavior, 107*, 159-173. https://doi.org/10.1016/j.anbehav.2015.06.008

Murray, L., Nguyen, H., Lee, Y. F., Remmenga, M. D., & Smith, D. W. (2012). Variance inflation factors in regression models with dummy variables. *Conference on Applied Statistics in Agriculture*. https://doi.org/10.4148/2475-7772.1034

Müller, C. A. Götz, S. K., & Kappeler, P. M. (2014). The impact of human disturbance on birds: A selective review*. Ecology and Evolution, 4*(11), https://doi.org/10.7882/FS.2008.023

Nácarová, J., Veselý, P., & Fuchs, R. (2018). Effects of the exploratory behavior to categorize a predator*.* Behavioural Processes, *151*, 89-95. https://doi.org/10.1016/j.beproc.2018.03.021

O'Hara, M., Mioduszewska, B., von Bayern, A., Auersperg, A., Bugnyar, T., Wilkinson, A., Huber, L., & Gajdon, G. K. (2017). The temporal dependence of exploration on neotic style in birds*. Scientific Reports, 7(1)*, 4742. https://doi.org/10.1038/s41598-017-04751-0

Osborne, J. (2010). Improving your data transformation: Applying the Box-Cox transformation. *Practical Assessment, Research, and Evaluation, 15*(1), 12. https://doi.org/10.7275/qbpc-gk17

Pisula, W., & Modlinska, K. (2023). Animals in search of stimulation and information: A review of over 10 years of our spontaneous exploration in rats as a response to novelty on low-stress paradigm*. Animal Behavior and Cognition, 10*(4), 287-303. https://doi.org/10.26451/abc.10.04.01.2023

Price, M. (2008). The impact of human disturbance on birds: A selective review*. Australian Zoologist, 34*(1), 99 -106. https://doi.org/10.7882/FS.2008.023

Quinn, J. L., Cole, E. F., Bates, J., Payne, R. W., & Cresswell, W. (2012). Personality predicts individual responsiveness to the risk of starvation and predation. *Proceeding of the Royal Society, Biological Sciences, 279*(173), 1919-1926. https://doi.org/10.1098/rspb.2011.2227

Réale, D., Reader, S. M., Sol, D., McDougall, P. T., & Dingemanse, N. J. (2007). Integrating animal temperament within ecology and evolution. *Biological Reviews*, *82*(2), 291–318. https://doi.org/10.1111/j.1469-185X.2007.00010.x

Romeu, J. L. (2003). *Anderson-Darling: A goodness of fit test for small samples assumptions* (Vol. 10, No. 5). Reliability Analysis Center (RAC), Department of Defense. https://web.cortland.edu/matresearch/AndrsDarlSTART.pdf

Rousseeuw, P., & Hubert, M. (2011). Robust statistics for outlier detection. *Wiley Interdisciplinary Reviews: Data Mining and Knowlegde Discovery, 1*(1), 73-79. https://doi.org/10.1002/widm.2

Scheiber, I. B. R., Weiß, B. M., Hemetsberger, J., & Kotrschal, K. (2013). *The social life of greylag geese: Patterns, mechanisms and evolutionary function in an avian model system*. Cambridge University Press

Schielzeth, H., & Nakagawa, S. (2013): Nested by design: Model fitting and interpretation in a model mixed era. *Journal of Animal Ecology, 82*(1), 1-7. https://doi.org/10.1111/j.2041-210x.2012.00251.x

Sih, A., Chung, H. J., Neylan, I., Ortiz-Jimenez, C., Sakai, O., & Szeligowski, R. (2023). Fear generalization and behavioral responses to multiple dangers. *Trends in Ecology & evolution*, *38* (4), 369-380. https://doi.org/10.1016/j.tree.2022.11.001

Skrondal, A. & Rabe-Hesketh, S. (2009). Prediction in multilevel generalized linear models. *Journal of the Royal Statistical Society*: *Series A (Statistics in Society), 172*(3), 659-687. https://doi.org/10.1111/j.1467-985X.2009.00587.x

Stahl, J., Tolsma, P. H., Loonen, M. J. J. E., & Drent, R. H. (2001). Subordinated explore but dominants profit: Resource competition in high Arctic barnacle goose flocks. *Animal Behavior, 61*(1), 257-264. https://doi.org/10.1006/anbe.2000.1564

Storms, R.F., Carere, C., Musters, R., van Gasteren, H., Verhulst, S., & Hemelrijk, C. K. (2022). Deterrence of birds with an artificial predator, the RobotFalcon*. Journal of the Royal Society Interface, 19*, 20220497. https://doi.org/10.1098/rsif.2022.0497

Stöwe, M., Bugnyar, T., Heinrich, B., & Kotrschal, K. (2006a). Effects of group size on approach to novel objects in ravens (*Corvus corax*)*, Ethology, 112*, 1079-1088. https://doi.org/10.1111/j.1439-0310.2006.01273.x

Stöwe, M, Bugnyar, T., Loretto, M. C, Schloegl, C., Range, F., & Kotrschal, K. (2006b). Novel object exploration in ravens (*Corvus corax*): effects of social relationships*. Behavioral Processes; 73*(1), 68-75. https://doi.org/10.1016/j.beproc.2006.03.015

Surlemont, M. A. (2025). *Not so bold after all – A study of personality and anti – predator responses in graylag geese (Masterthesis),* University of Vienna, https://utheses.univie.ac.at/detail/74669/

Szipl, G., Loth, A., Wascher, C. A. F., Hemetsberger, J., Kotrschal, K., & Frigerio, D. (2019). Parental behaviour and family proximity as key to gosling survival in Greylag Geese (*Anser anser*)*, Journal of Ornithology, 160,* 473–483. https://doi.org/10.1007/s10336-019-01638-x

Takola, E., Krause, E. T, Müller, C., & Schielzeth, H. (2021). Novelty at seconds glance: a critical appraisal of the novel object paradigm based on meta-analysis*. Animal Behavior, 180*, 123-142. https://doi.org/10.1016/j.anbehav.2021.07.018

Tebbich, S., Fessl B., & Blomqvist, D. (2010). Exploration and ecology in Darwin finches. *Evolutionary Ecology, 23,* 591-605. https://doi.org/10.1007/s10682-008-9257-1

Van Oers K., Drent P. J., de Goede P., & van Noordwijk A.J. (2004). Realized heritability and repeatability of risk-raking in relation to avian personalities*. Proceedings of the Royal Society, B: Biological science, 271*(1534), 65-73. https://doi.org/10.1098/rspb.2003.2518

Verbeek, M. E. M., Drent, P. J., & Wiepkema, P. R. (1994). Consistent individual differences in early exploratory behavior of male great tits. *Animal Behavior*, *48*(5), 11133-1121. https://doi.org/10.1006/anbe.1994.1344

Wascher, C. A. F., Weiß, B. M., Arnold, W., & Kotrschal K. (2012). Physiological implications of pair-bond status in greylag geese. *Biology Letters*, *8*(2), 347-350. https://doi.org/10.1098/rsbl.2011.0917

Watson, M., Aebischer, N. J., & Cresswell, W. (2007). Vigilance and fitness in grey partridges *Perdix perdix*: The effects of group size and foraging-vigilance-trade-off on predation mortality. *Journal of Animal Ecology*, *76*(1), 211-221. https://doi.org/10.1111/j.1365-2656.2006.01194.x

Winkler, H., & Leisler, B. (1999). Exploration and curiosity in birds: functions and mechanism. In N. J. Adams & R. H. Slotow (Eds.), *Proceeding of the 22nd International Ornithological Congress* (pp. 915 - 932), BirdLife South Africa, https://www.internationalornithology.org/PROCEEDINGS_Durban/Symposium/S16/S16.5.htm

Wolf, M., Van Doorn, G., & Leimar, O. (2007). Life history trade-offs favour the evolution of animal personalities. *Nature 447*, 581-584. https://doi.org/10.1038/nature05835

Zaynagutdinova, E., Karenina, K., & Giljov, A. (2020). Lateralization of vigilance in geese: Influence of flock size and distance to the source of disturbance. *Biological Communication*, *65*(3), 252-261. https://doi.org/10.21638/spbu03.2020.305

9. Appendix

9.1 Feeding exploration score comparison

Table 2: Tukey adjusted pairwise-comparison for the five different scores (-2, -1,0,1,2) during the "exposure phase" in correlation to the feeding duration (seconds). The exploration score -2 indicating a low tendency of exploratory behavior and an increase of the score leads to an increase of the willingness to explore. No significant p-values were detected, indicating no significant difference in feeding duration among the quartiles during this phase, **Estimate**: describes an effect of a predictor variable, **Standard Error**: variability of the estimated coefficient, **z-value:** ratio of the estimate to the standard error, Pr (>|z|): **P-value** indicating significance

contrast	estimate	SE	z.ratio	p.value
Exploration score (-2) – Exploration score (-1)	0.05	0.09	0.60	0.974
Exploration score (-2) – Exploration score (0)	-0.07	0.10	-0.72	0.951
Exploration score (-2) – Exploration score (1)	-0.03	0.12	-0.29	0.998
Exploration score (-2) – Exploration score (2)	-0.01	0.10	-0.18	0.999
Exploration score (-1) – Exploration score (0)	-0.13	0.09	-1.41	0.618
Exploration score (-1) – Exploration score (1)	-0.09	0.11	0.84	0.918
Exploration score (-1) – Exploration score (2)	-0.07	0.09	-0.82	0.924
Exploration score (0) – Exploration score (1)	0.04	0.12	0.33	0.997
Exploration score (0) – Exploration score (2)	0.05	0.10	0.54	0.983
Exploration score (1) – Exploration score (2)	0.01	0.12	0.13	0.999

Table 3: Tukey adjusted pairwise-comparison for the five different exploration scores (-2,-1,0,1,2) during the "after landing phase" in correlation to the feeding duration (seconds). The exploration score -2 indicating a low tendency of exploratory behavior and an increase of the score leads to an increase of the willingness to explore. No significant p-values were detected, indicating no significant difference in feeding duration among the quartiles during this phase, **Estimate**: describes an effect of a predictor variable, **Standard Error**: variability of the estimated coefficient, **z-value:** ratio of the estimate to the standard error, Pr (>|z|): **P-value** indicating significance

contrast	estimate	SE	z.ratio	p.value
Exploration score (-2) – Exploration score (-1)	0.03	0.13	0.22	0.999
Exploration score (-2) – Exploration score (0)	-0.31	0.18	-1.75	0.397
Exploration score (-2) – Exploration score (1)	-0.03	0.14	-0.23	0.999
Exploration score (-2) – Exploration score (2)	-0.05	0.14	-0.33	0.997
Exploration score (-1) – Exploration score (0)	-0.34	0.18	-1.91	0.308
Exploration score (-1) – Exploration score (1)	-0.003	0.14	0.02	1.000
Exploration score (-1) – Exploration score (2)	-0.08	0.14	-0.54	0.982
Exploration score (0) – Exploration score (1)	0.35	0.18	1.85	0.341
Exploration score (0) – Exploration score (2)	0.26	0.19	1.36	0.650
Exploration score (1) – Exploration score (2)	-0.08	0.15	-0.54	0.982

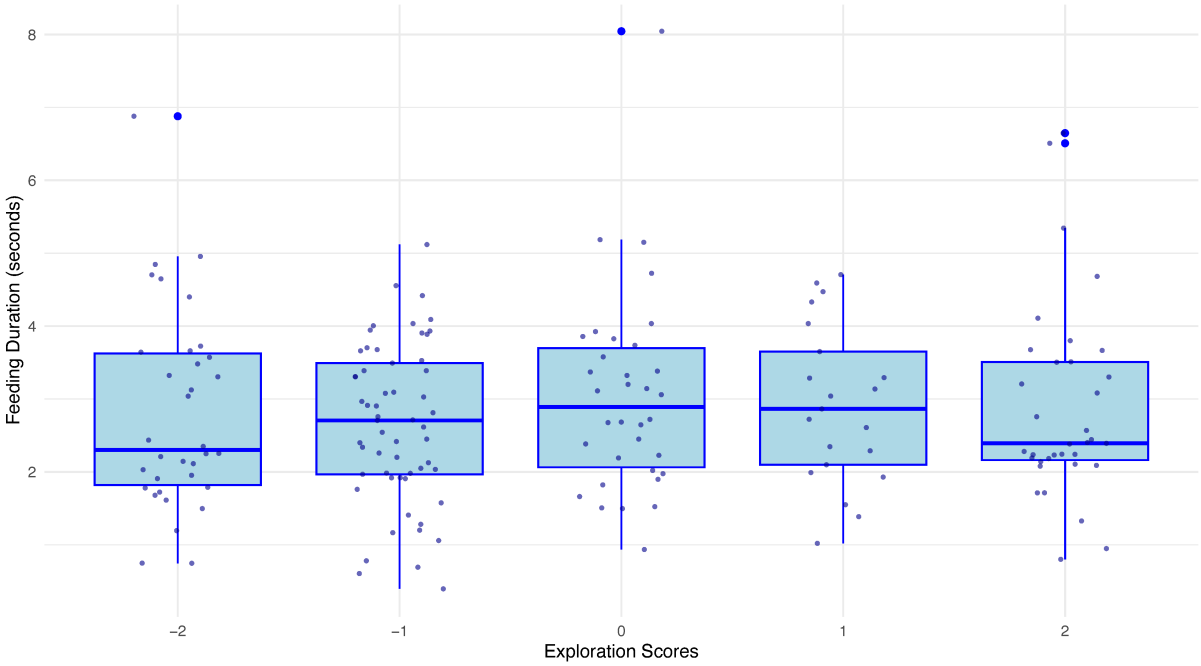


Figure 5: A Tukey-adjusted pairwise comparison for the exploration score divided into 5 bins (-2, -1, 0, 1 and 2) corresponding to a range of Delta Latency values from -300 to 300. The exploration score is plotted against the feeding duration (seconds) during the "exposure" phase to examine potential differences between the scores. No significant differences have been found across all the exploration scores.

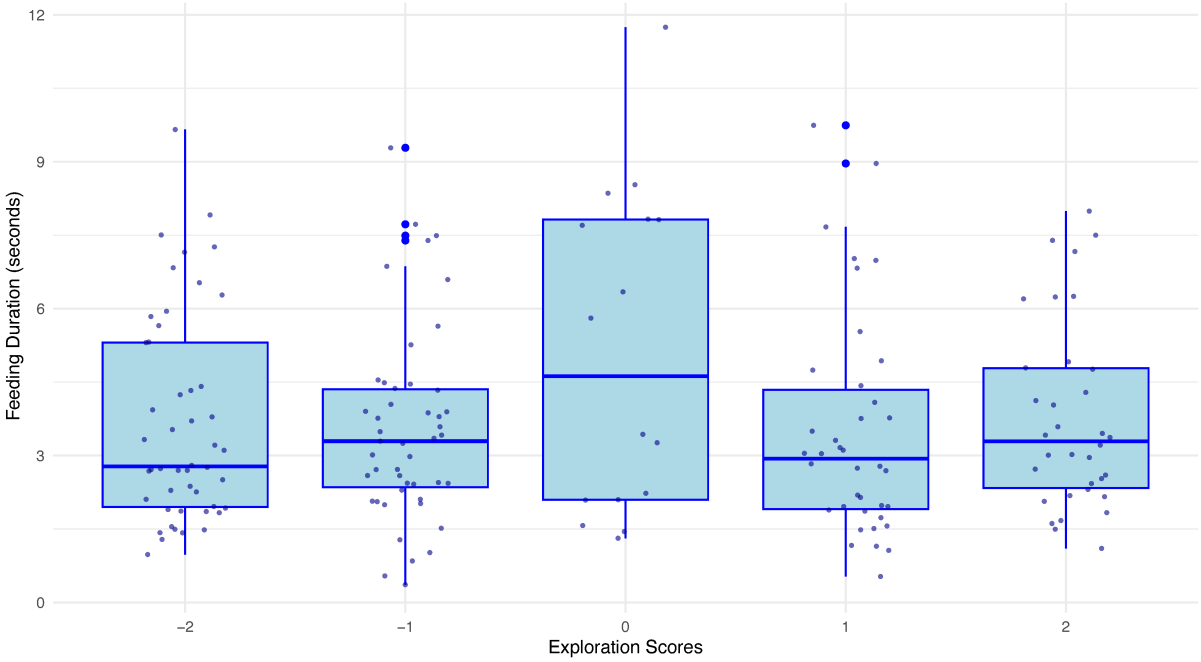


Figure 6: A Tukey-adjusted pairwise comparison for the exploration score divided into 5 bins (-2,-1, 0, 1 and 2) corresponding to a range of Delta Latency values from -300 to 300. The exploration score is plotted against the feeding duration (seconds) during the "after landing" phase to examine potential differences between the scores. No significant differences have been found across all the exploration scores.

9.2 Different Vigilance behaviors

9.2.1 Short neck

Across the different phases (before launch, exposure and after landing), there is a variation of the short neck duration (seconds). The before launch duration shows a significant negative relationship (Estimate = − 0.19 ± 0.06, p = 0.002 **) suggesting a decrease in short neck responses compared to the exposure phase. In comparison, there is just a marginally significant value for the phase after landing duration and is just indicating a negative trend. Other factors such as the exploration quartiles, age, sex or pairing status do not significantly influence the response variable (Figure 2).

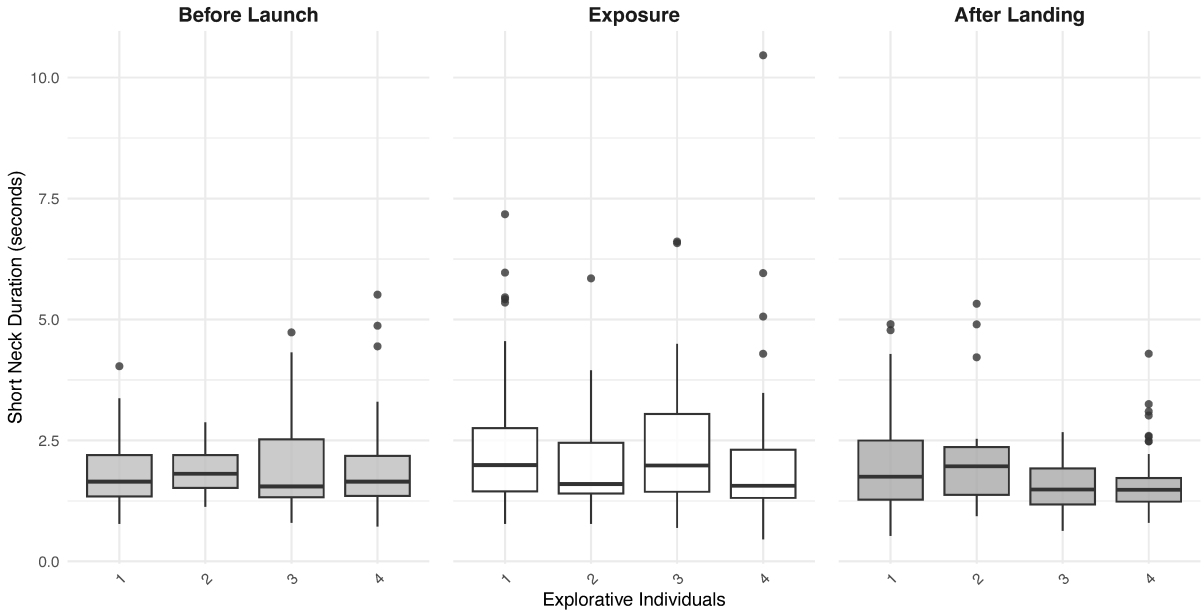


Figure 7: Short Neck duration (seconds) during three different phases: before launch, exposure and after landing. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase**: Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. The four quartiles (1,2,3,4) represent the explorative individuals divided into weak explorers (Q4) to the strongest explorer (Q1).

Significant effects include a negative relationship between the before launch phase duration and the response variable (*Estimate = − 0.19 ± 0.06, p = 0.002 **).* Between exposure and after landing, a decrease of short neck behavior is given but with a marginal significance (*Estimate = − 0.12 ± 0.07, p = 0.083)* . Other predictors and interactions show no significant influence.

Table 4: Results from the gamma GLMM function, indicating the relationship between the duration of short neck as a response variable in correlation to the phases (before launch, exposure phase as reference phase and after landing) and the predictor exploration. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase**: Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon.

Additional variables include age, sex and pair status. Random effects were Behavior instance (= OLRE, variance: 0.154, p = 0.405), Bird ID (variance: 0.007, p = 0.008), sector (variance: 0.005, p = 0.077) and Exposure Day (variance: 0.01, p = 0.102). Significant effects are labelled with * (p < 0.05), ** (p < 0.01) , *** (p < 0.001). Marginally significant results are marked with a dot (p < 0.10)

Estimate: describes an effect of a predictor variable, **Standard Error**: variability of the estimated coefficient, **z-value:** ratio of the estimate to the standard error and Pr (>|z|): **P-value** indicating significance

A: Anova deviance results with **Chisq**: Chi-square statistic

	Estimate	SE	z value	Pr(>|z|)	Chisq	Df	Sign
(Intercept)	0.62	0.14	4.18	< 0.001			***
phasebefore_launch_duration	-0.19	0.06	-3.03	0.002			**
phaseafter_landing_duration	-0.12	0.07	-1.73	0.083			.
exploration2	-0.06	0.11	-0.53	0.593			
exploration3	0.12	0.11	1.02	0.305			
exploration4	-0.11	0.10	-1.10	0.268			
sqrt(Age.y)[A]	0.03	0.03	0.85	0.390	0.73	1	
Sex.yM[A]	-0.01	0.08	-0.14	0.885	0.01	1	
Pairing.yunpaired[A]	-0.07	0.12	-0.59	0.555	0.32	1	
phasebefore_launch_duration:exploration2	0.18	0.12	1.46	0.141			
phaseafter_landing_duration:exploration2	0.12	0.14	0.82	0.412			
phasebefore_launch_duration:exploration3	-0.0007	0.14	-0.006	0.995			
phaseafter_landing_duration:exploration3	-0.23	0.15	-1.47	0.139			
phasebefore_launch_duration:exploration4	0.13	0.10	1.37	0.169			
phaseafter_landing_duration:exploration4	-0.015	0.11	-0.14	0.888			
Sex.yM:Pairing.yunpaired	0.05	0.17	0.32	0.743	0.10	1	
Phase[A]				0.001	12.77	2	**
Exploration[A]				0.626	1.74	3	
Phase: exploration[A]				0.344	6.75	6	

9.2.2 Long Neck

The long neck duration (seconds) for explorative individuals showed a variation within the phases (before launch, exposure and after landing). The influence of the before launch phase on the long neck duration was not significant (Estimate = −0.02 ± 0.13, p = 0.826) whereas the after-landing phase showed a significant negative value, indicating a decrease in behavioral responses compared to the exposure phase (Estimate = −0.41 ± 0.13, p = 0.001 **).

The covariates Pairing / unpaired (Estimate = −0.45 ± 0.18, p = 0.016*) showed a significance as well, highlighting the interaction and independent effects of Sex and Pairing status on the long neck duration (Figure 3).

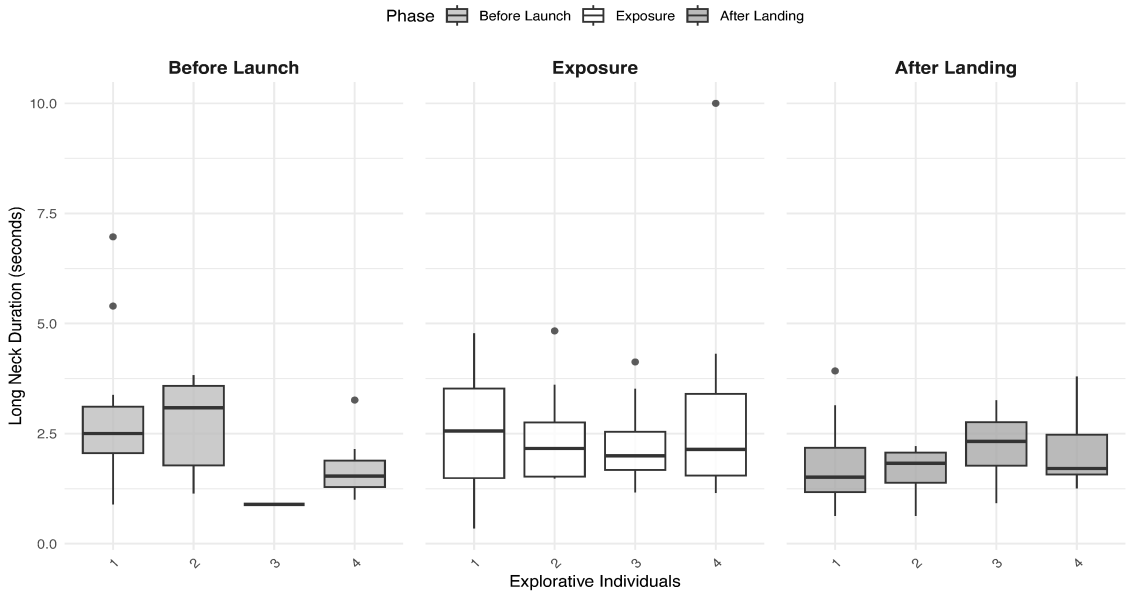


Figure 8: Long Neck duration across behavioral phases divided into before launch, exposure and after landing, stratified by exploration quartiles (labelled 1-4, from high (1) to low (4) exploration tendency**. Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase**: Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Phase after landing duration showed a significant negative estimate (*Estimate* = −0.41 ± *0.13*, p = 0.001**) indicating a lower Long Neck duration compared to the reference phase.

Table 5: Results of the gamma GLMM investigating the relationship between long neck duration and explanatory variables including phase and the exploration personality trait and other independent variables like age, sex, sector and Exposure day. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase:** Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. . Random effects were Behavior instance (= OLRE, variance: 0.06, p:value = 0.249), Bird ID (variance: 0.001 p:value = 0.001) and sector (variance: 8.164e-11, p-value: < 0.001) . Significance highlighted with *, ($p < 0.05$), ** ($p < 0.01$) and *** ($p < 0.001$). Marginal effects are marked with a dot ($p < 0.10$), **Estimate**: describes an effect of a predictor variable, **Standard Error**: variability of the estimated coefficient, **z-value:** ratio of the estimate to the standard error and Pr (>|z|): **P-value** indicating significance
A: Anova deviance results with **Chisq**: Chi-square statistic

	Estimate	SE	z value	Pr(>|z|)	Chisq	Df	Sign
(Intercept)	0.92	0.17	5.14	< 0.001			***
phasebefore_launch_duration	-0.02	0.13	-0.17	0.859			
phaseafter_landing_duration	-0.41	0.13	-3.15	0.001			**
exploration2	0.02	0.14	0.17	0.862			
exploration3	-0.20	0.15	-1.34	0.179			
exploration4	0.04	0.12	0.37	0.710			
sqrt(Age.y)	0.02	0.05	0.43	0.665	0.18	1	
Sex.yM	-0.05	0.10	-0.54	0.586	0.27	1	
Pairing.yunpaired	-0.45	0.18	-2.38	0.016			*
phasebefore_launch_duration:exploration2	0.009	0.21	0.04	0.965			
phaseafter_landing_duration:exploration2	-0.12	0.27	-0.46	0.643			
phasebefore_launch_duration:exploration3	-0.34	0.29	-1.15	0.248			
phaseafter_landing_duration:exploration3	0.38	0.23	1.66	0.096			.
phasebefore_launch_duration:exploration4	-0.39	0.18	-2.17	0.029			*
phaseafter_landing_duration:exploration4	0.20	0.19	1.06	0.286			
Sex.yM:Pairing.yunpaired	0.41	0.21	1.92	0.054	3.69	1	.
phase				0.0004	15.43	2	***
exploration				0.599	0.27	1	
Phase:exploration				0.072	14.14	6	

9.2.3 One eye up

The response variable (One eye up duration in seconds) is influences by multiple predictors. For example, the before launch duration has a negative effect (Estimate = −0.35 ± 0.14, p = 0.015*) suggesting a decrease in the one eye up posture within this phase compared to the exposure phase. A negative effect is just visible during the after-landing phase (Estimate = -0.23 ± 0.20, p = 0.242*)*, but with no significance p-value.

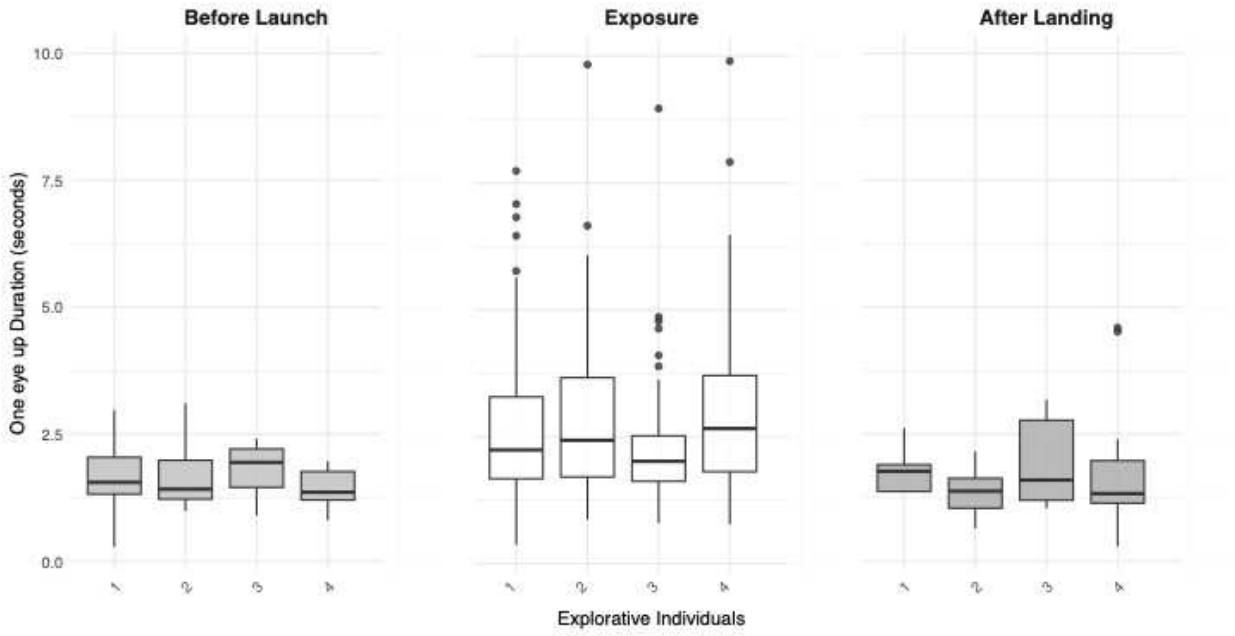


Figure 9: The behavioral response „One eye up" – posture in seconds in relationship to the exploration quartiles (1,2,3,4) and the phase elements (before launch, exposure phase and after landing). **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon**), Exposure phase**: Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Significant negative effect for before launch duration (*Estimate* = −0.35 ± *0.14*, p = 0.015) but no significance for the after-landing duration (*Estimate* = −0.23 ± *0.20*, p = 0.242).

Table 6: Output of the gamma GLMM of one-eye- up behavior with the response variable duration in relation to the phase (exposure as a reference phase) and the exploration (predictor), other independent variables like sector, sex, age and pairing status are also included in the calculation. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase**: Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Significant effects are highlighted with * ($p < 0.05$), ** ($p < 0.01$) and ** ($p < 0.001$). Marginal effects are marked with a dot ($p < 0.10$). Random effects were Behavior instance (= OLRE, variance: 0.01, p = 0.355), Bird ID (variance: 4.475e-09, p = < 0.001) and sector (variance: 7.164e-11, p = < 0.001). **Estimate**: describes an effect of a predictor variable, **Standard Error**: variability of the estimated coefficient, **z-value:** ratio of the estimate to the standard error and Pr (>|z|): **P-value** indicating significance, **A:** Anova deviance results with **Chisq**: Chi-square statistic

	Estimate	SE	z value	Pr(>|z|)	Chisq	Df	Sign
(Intercept)	0.78	0.12	6.50	< 0.001			***
phasebefore_launch_duration	-0.35	0.14	-2.41	0.015			*
phaseafter_landing_duration	-0.23	0.20	-1.17	0.242			
exploration2	0.007	0.10	0.07	0.944			
exploration3	-0.03	0.10	-0.38	0.702			
exploration4	0.21	0.08	2.64	0.008			**
sqrt(Age.y)[A]	0.002	0.03	0.07	0.939	0.005	1	
Sex.yM[A]	0.03	0.06	0.52	0.602	0.27	1	
Pairing.yunpaired	0.10	0.07	1.38	0.165	3.69	6	
phasebefore_launch_duration:exploration2	0.04	0.22	0.19	0.849			
phaseafter_landing_duration:exploration2	-0.30	0.29	-1.01	0.311			
phasebefore_launch_duration:exploration3	0.14	0.29	0.47	0.635			
phaseafter_landing_duration:exploration3	0.18	0.40	0.45	0.648			
phasebefore_launch_duration:exploration4	-0.22	0.24	-0.93	0.348			
phaseafter_landing_duration:exploration4	-0.21	0.26	-0.81	0.415			
Phase[A]				< 0.001	26.41	2	***
Exploration[A]				0.058	7.47	3	.
Phase: exploration[A]				0.717	3.69	6	

9.2.4 Total vigilance

The total vigilance duration in seconds including the behavioral responses short neck (V1), long neck (V2) and one-eye-up (V3). The phase before launch duration showed no significance (Estimate = -0.12 ± 0.09, p = 0.194) but the phase after landing duration showed a negative estimate and a significant p-value (Estimate = -0.28 ± 0.10, p = 0.00726 **), suggesting a lower vigilance compared to the exposure phase. Other covariates such as Sex, Age and Pairing status did not have an influence (Figure 9).

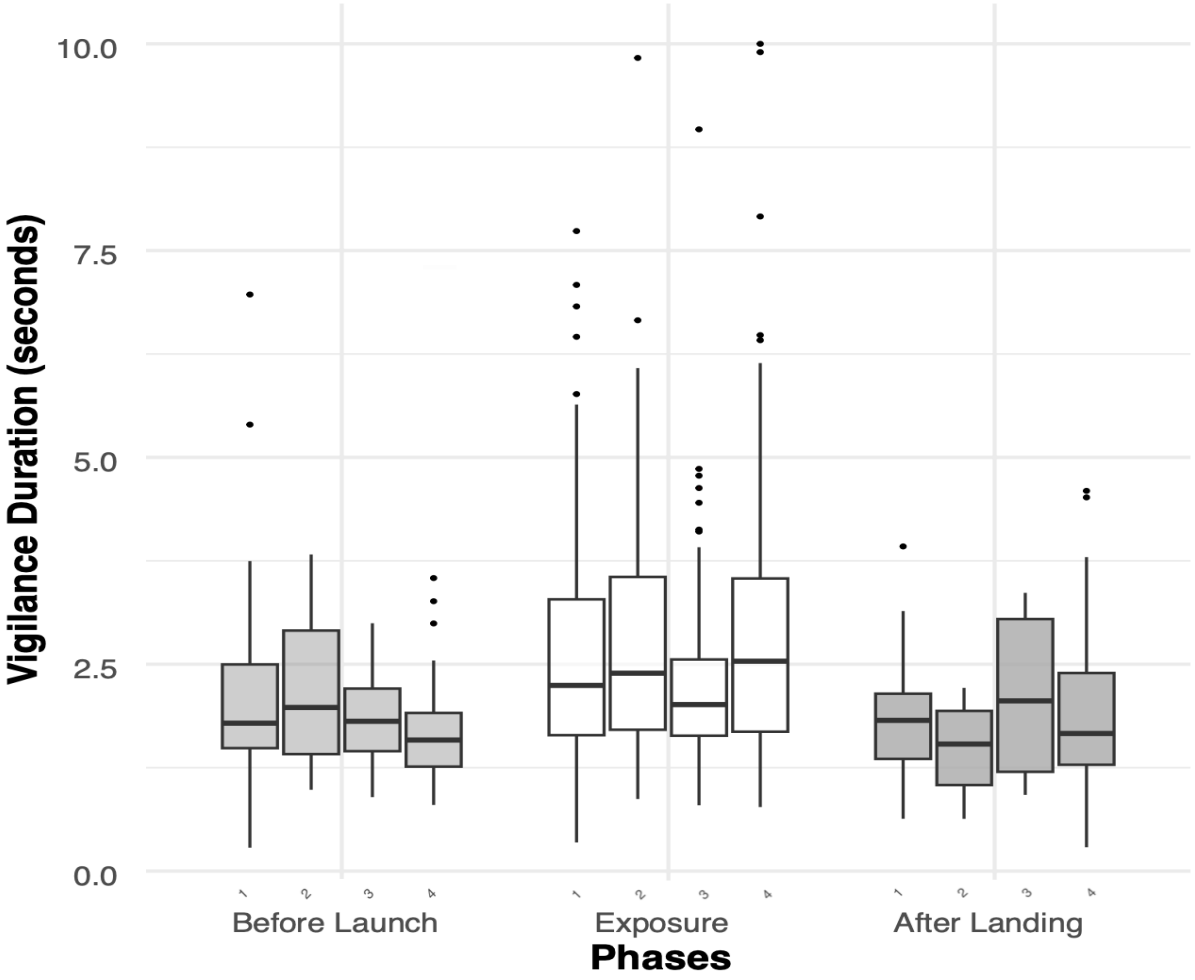


Figure 10: The total vigilance duration in seconds across three different phases (before launch, exposure and after landing) and the four exploration quartiles (1 = strong, 2, 3, 4 = weak explorers). **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase:** Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Phase before launch duration not statistically significant (Estimate = -0.12 ± 0.09, p = 0.194) but phase after landing duration has a negative effect (Estimate = -0.28 ± 0.10, p = 0.00726), leading to a decrease in vigilance response compared to the exposure phase.

Table 7: Results from the gamma GLMM function, indicating the relationship between the vigilance duration as a response variable in correlation to the phases (before launch, exposure phase and after landing) and personality exploration. Independent variables include sex, age and pairing status, random effect. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase**: Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Significant values are marked with * (p < 0.05) ** (p < 0.01) and *** (p < 0.001), marginal significance highlighted with a dot (p < 0.10). Random effects were Behavior instance (= OLRE, variance: 0.006, p:value = 0.002), Bird ID (variance: 2.964e-12, p = < 0.001) and surveyor (variance: 1.086e-09, p = < 0.001), Coder ID (variance: 7.844e-04, p = 0.002) and Exposure Day (variance: 9.591e-03, p = 0.009)

Estimate: describes an effect of a predictor variable, **Standard Error**: variability of the estimated coefficient, **z-value:** ratio of the estimate to the standard error and Pr (>|z|): **P-value** indicating significance

A: Anova deviance results with **Chisq**: Chi-square statistic

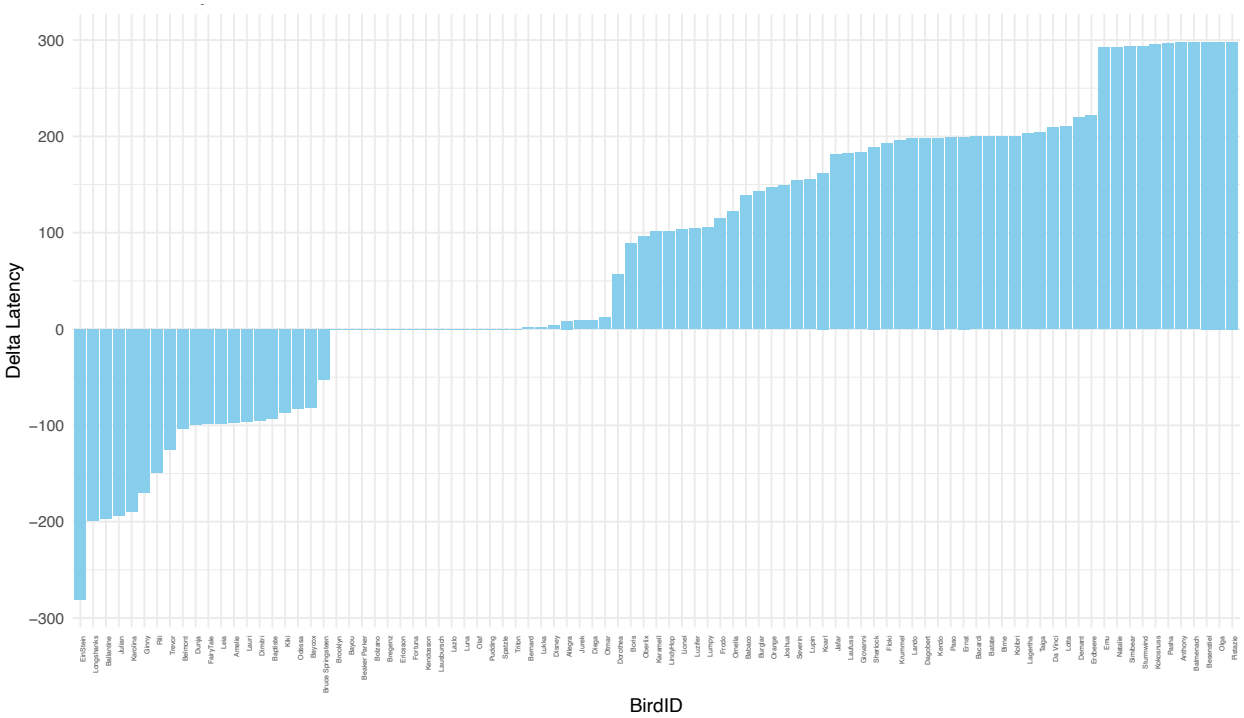
	Estimate	SE	z value	Pr(>|z|)	Chisq	Df	Sign
(Intercept)	0.95	0.10	8.79	< 0.001			***
phasebefore_launch_duration	-0.12	0.09	-1.29	0.194			
phaseafter_landing_duration	-0.28	0.10	-2.68	0.007			**
exploration2	0.01	0.08	0.18	0.853			
exploration3	-0.08	0.08	-1.10	0.269			
exploration4	0.11	0.06	1.70	0.088			.
sqrt(Age.y)[A]	-0.02	0.02	-0.73	0.462	0.48	1	
Pairing.yunpaired	-0.01	0.05	-0.25	0.798			
Sex.yM[A]	0.01	0.04	0.26	0.792	0	1	
phasebefore_launch_duration:exploration2	-0.02	0.15	-0.18	0.855			
phaseafter_landing_duration:exploration2	-0.23	0.19	-1.23	0.217			
phasebefore_launch_duration:exploration3	-0.14	0.21	-0.68	0.491			
phaseafter_landing_duration:exploration3	0.21	0.19	1.09	0.275			
phasebefore_launch_duration:exploration4	-0.34	0.14	-2.43	0.014			*
phaseafter_landing_duration:exploration4	-0.06	0.15	-0.43	0.664			
phase [A]				<0.001	32.71	2	***
exploration [A]				0.348	2.10	2	
Phase:exploration[A]				0.141	6.88	4	

Table 8: The normalized percentage (%) and the total duration (in seconds) of the two different behaviors foraging (V0 non vigilant) and overall vigilance responses (including V1 short neck, V2 long neck and V3 one-eye-up) in relation to the exploration score (-2,-1,0,1,2) within the three different phases before launch, exposure phase and after landing. The exploration score -2 indicating a low tendency of exploratory behavior and an increase of the score leads to an increase of the willingness to explore. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase**: Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon.

Exploration Score	Phase	Vigilance Status	Total Duration	Normalized %
2	Before launch	foraging	259.34	~85.48%
2	Before launch	vigilant	44.09	~14.52%
1	Before launch	foraging	208.79	~82.99%
1	Before launch	vigilant	42.77	~17.00%
0	Before launch	foraging	210.05	~81.19%
0	Before launch	vigilant	48.67	~18.81%
-1	Before launch	foraging	305.87	~89.63%
-1	Before launch	vigilant	35.41	~10.37%
-2	Before launch	foraging	420.62	~83.63%
-2	Before launch	vigilant	82.35	~16.38%
2	Exposure	foraging	196.13	~50.39%
2	Exposure	vigilant	193.12	~49.61%
1	Exposure	foraging	98.57	~34.96%
1	Exposure	vigilant	183.44	~65.05%
0	Exposure	foraging	147.62	~35.25%
0	Exposure	vigilant	271.19	~64.75%
-1	Exposure	foraging	198.51	~40.76%
-1	Exposure	vigilant	288.55	~59.42%
-2	Exposure	foraging	133.83	~24.52%
-2	Exposure	vigilant	411.92	~75.48%
2	After landing	foraging	251.33	~85.81%
2	After landing	vigilant	41.56	~14.19%
1	After landing	foraging	186.38	~89.81%
1	After landing	vigilant	21.14	~10.19%
0	After landing	foraging	168.01	~90.83%
0	After landing	vigilant	16.95	~9.17%
-1	After landing	foraging	245.94	~86.38%
-1	After landing	vigilant	38.78	~13.62%
-2	After landing	foraging	249.02	~82.90%
-2	After landing	vigilant	51.38	~17.10%

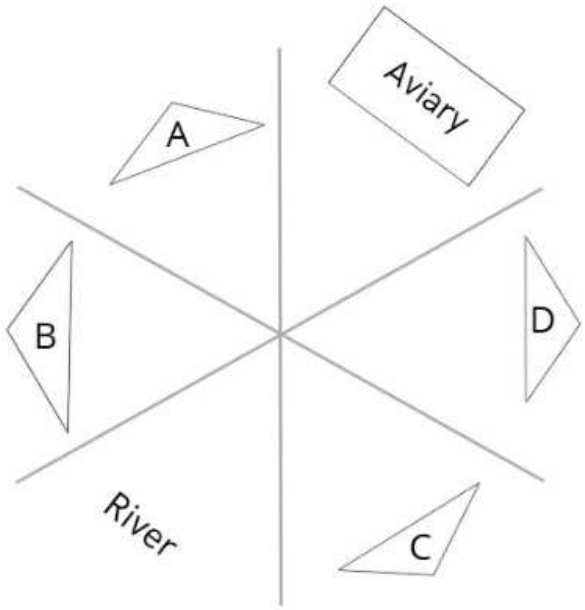
10. Supplementary Material

10.1 Delta Latency



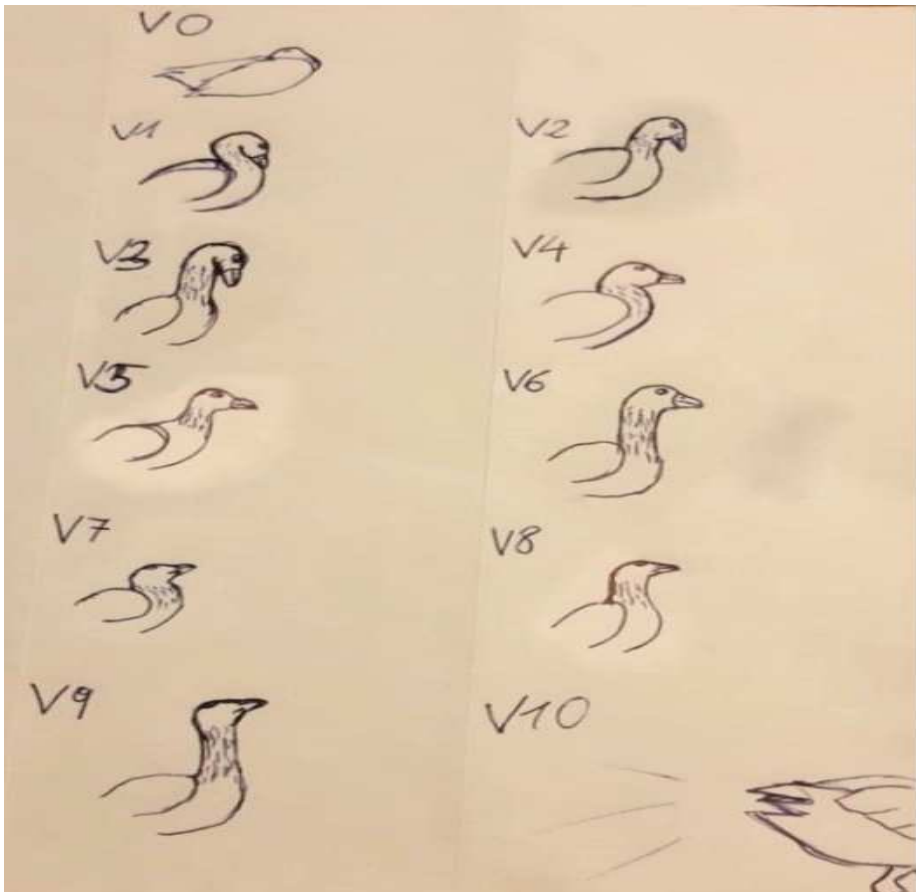
Supplementary Figure 1: Delta Latency or neophobia scores, measurement for the differences in feeding latencies between the presence of a novel object and a familiar food tray and the baseline (Kleindorfer et. al., 2024b). On the x-axis are the geese with the specific names (marked as BirdID) and the different values of the Delta Latency on the y-axis with a range from -300 to 300 (unit: seconds), indicating that a decrease in Delta Latency leads to an increase of the exploration tendency and vice versa

10.2 experimental site classification

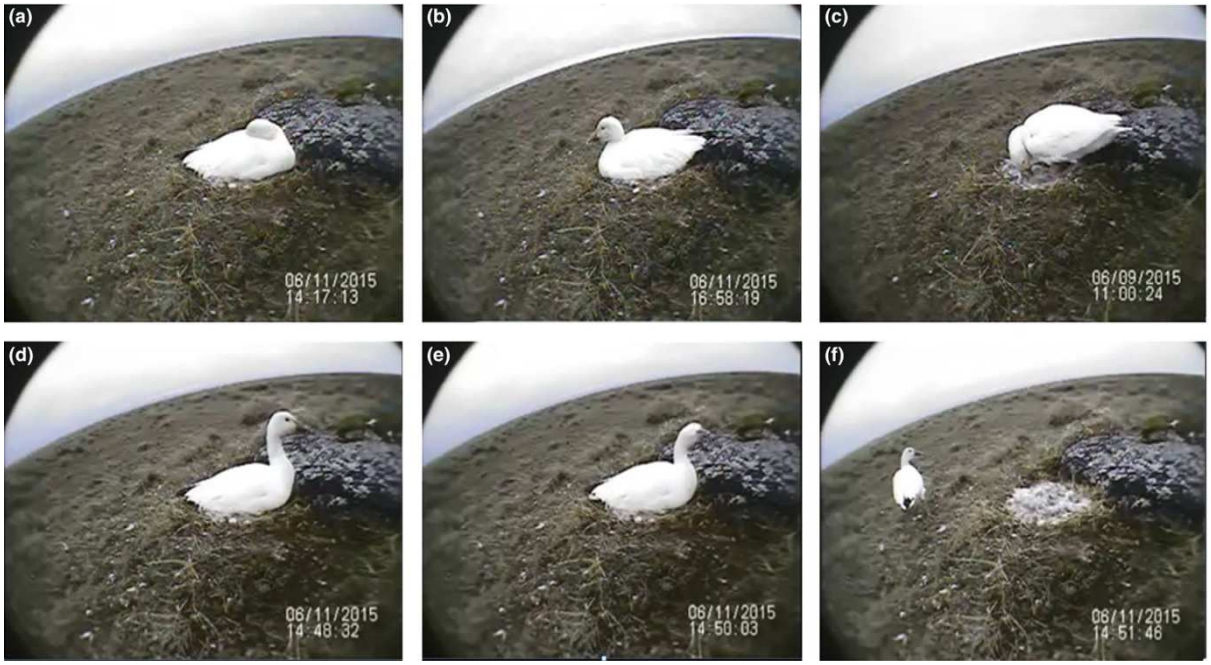


Supplementary Figure 2: The experimental site at Auinger Hof, featuring multiple feeding trays positioned within a designated area labeled A-D. The aviary includes a section with a cage used for temporarily holding individuals in captivity. The river section is situated next to B and C and additionally facing the Obergansbach waterbody

10.3 Ethograms



Supplementary Figure 3: Ethogram from Konrad Lorenz (1988) showing the different vigilance responses from V0 -10, VO indicates a non-vigilant state where the goose' head is tucked, V1 short neck: the beak is down, V2: mid neck and the beak is down, as well as in the long neck state (V3), V4 is a short neck position where the beak is pointing straight, V5 indicated mid neck with a straight beak position, V6 is long neck with a straight beak, V7 is a short neck with an one-eye up posture, where the head is tilted, V8 is the one-eye-up posture only, V9 one-eye up with a long neck and V10 is a flight response



Supplementary Figure 4: An Ethogram of the Vigilance behavior from Barnas et.al (2018) with a nesting waterfowl, first picture (a) illustrates the bird in a resting position (b) Low Scan behavior, (c) maintenance at the nest, (d) high Scan, (e) Head Cock, (f) Off Nest

Supplementary Figure 5: Classification of the behavioral responses divided into non-vigilant and vigilant:

VO-non feeding: *represents a non-vigilant state where the individual is either looking at the ground, resting or sleeping etc.*

VO-feeding*: non-vigilant state characterized by focused foraging activity with attention directed toward the ground*

V1 short neck*: first state of vigilance, indicating a moderate alertness where the beak held straight*

V2 long neck*: heightened state of vigilance characterized by an elongated neck and the beak pointing upward*

V3 one – eye up*: highest level of alertness where the head tilted, and the goose focuses on the predator using only one eye*

10.4 Model fitting

Supplementary Table 1: Output from a generalized linear mixed model (GLMM) consisting of the behavioral phases (with exposure as the reference phase), analyzing the duration of the feeding behavior across the different phases (before launch, exposure and after landing) in relation to the predictor exploration. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase**: Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon.

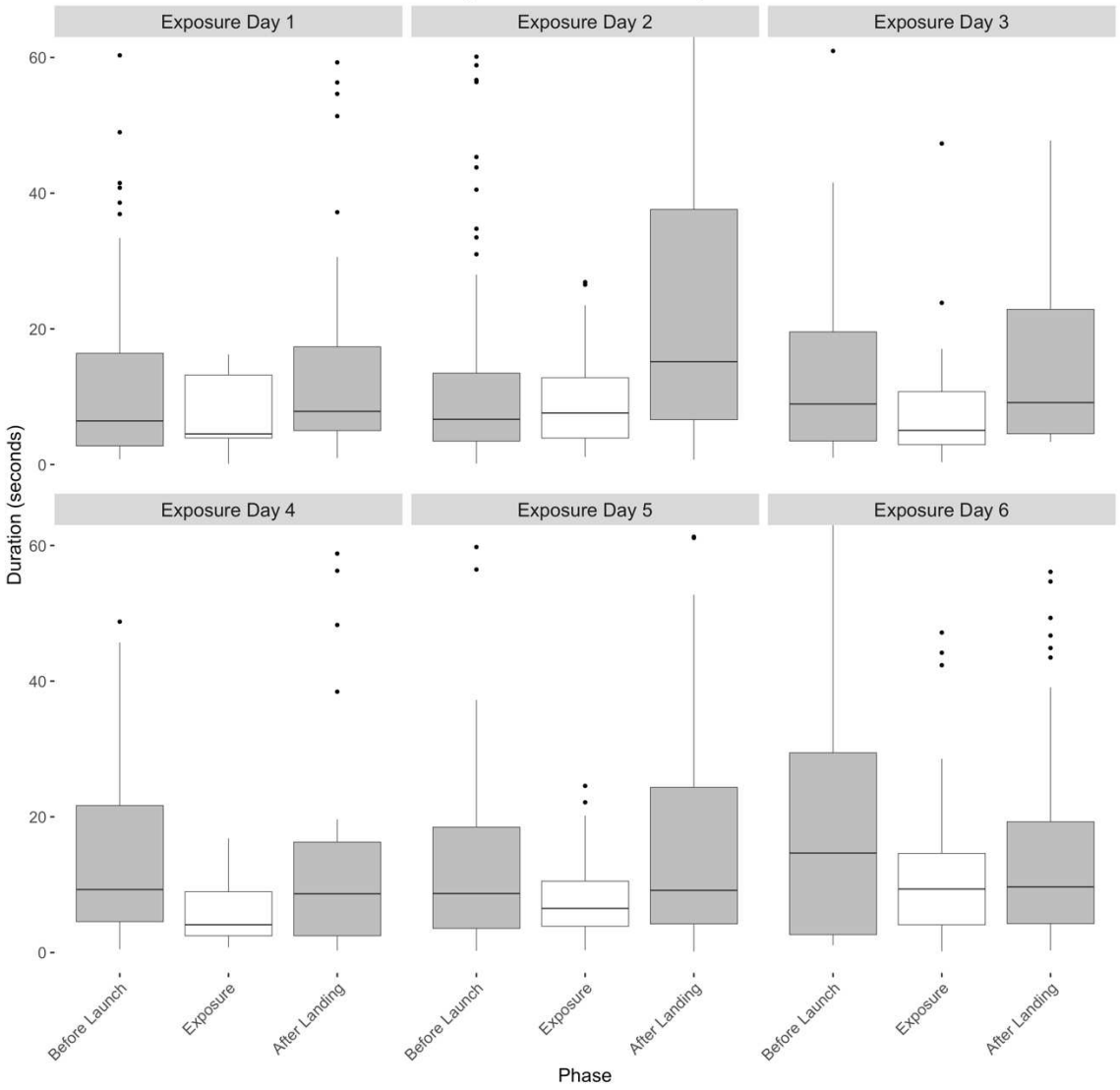
Other independent variables include age and random factors were Behavior instance (= OLRE, variance: 0.031, p = 0.178) and Bird ID (variance: 0.008, p = 0.094). Significant results are highlighted with * (p < 0.05), ** (p < 0.01) and *** (p < 0.001), marginally significant results are marked with a dot (p < 0.10).

Estimate: describes an effect of a predictor variable, **Standard Error**: variability of the estimated coefficient, **z-value:** ratio of the estimate to the standard error and Pr (>|z|): **P-value** indicating significance

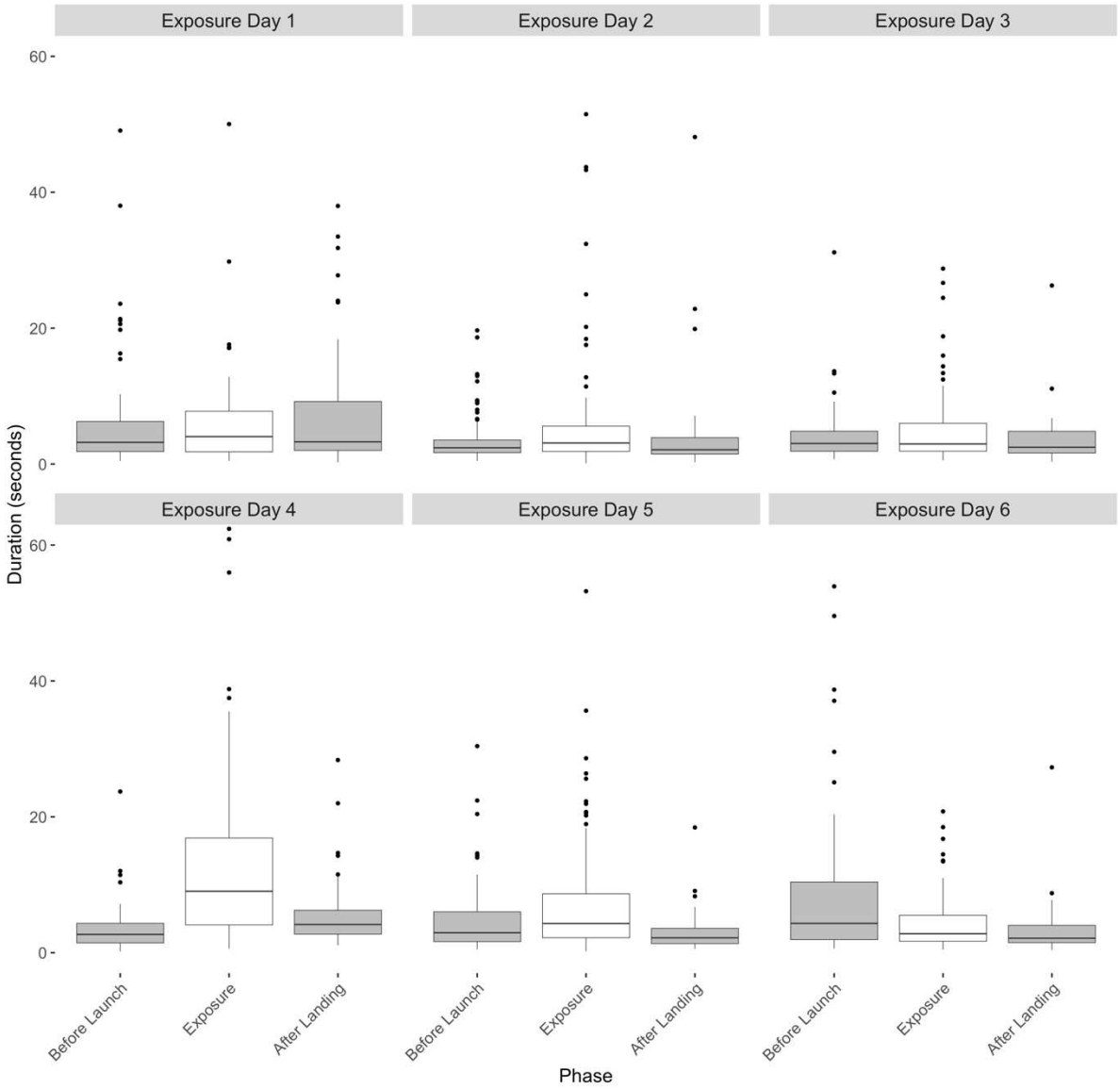
A: Anova deviance results with **Chisq**: Chi-square statistic

	Estimate	Std. Error	z value	Pr(>|z|)	Chisq	Df	Sign
(Intercept)	0.87	0.09	9.51	< 0.001			***
phasebefore_launch_duration	0.23	0.05	4.00	< 0.001			***
phaseafter_landing_duration	0.36	0.06	5.93	< 0.001			***
exploration2	0.10	0.21	0.48	0.624			
exploration3	-0.13	0.09	-1.35	0.175			
exploration4	-0.08	0.08	-0.97	0.328			
sqrt(Age.y)[A]	0.05	0.02	1.95	0.051	3.8	1	.
phasebefore_launch_duration:exploration2	-0.22	0.23	-0.95	0.337			
phaseafter_landing_duration:exploration2	-0.48	0.26	-1.79	0.073			.
phasebefore_launch_duration:exploration3	0.08	0.12	0.68	0.495			
phaseafter_landing_duration:exploration3	-0.11	0.12	-0.89	0.372			
phasebefore_launch_duration:exploration4	-0.11	0.09	-1.29	0.194			
phaseafter_landing_duration:exploration4	-0.04	0.10	-0.46	0.644			
Phase[A]				< 0.001	52.52	2	***
exploration[A]				0.014	10.49	3	*
Phase: exploration[A]				0.193	8.66	6	

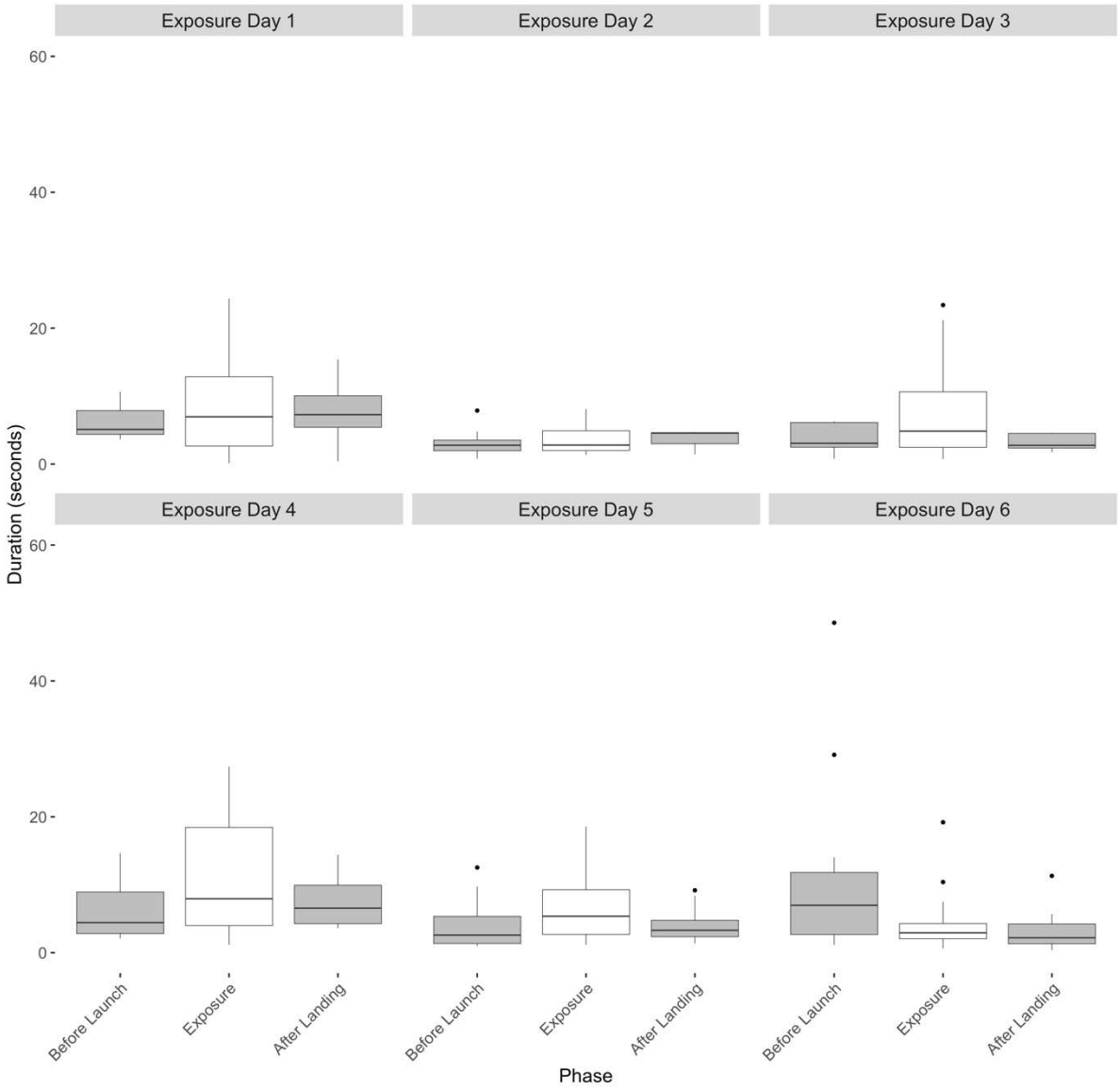
10.5 Total duration of the behavioral responses within the experimental phases



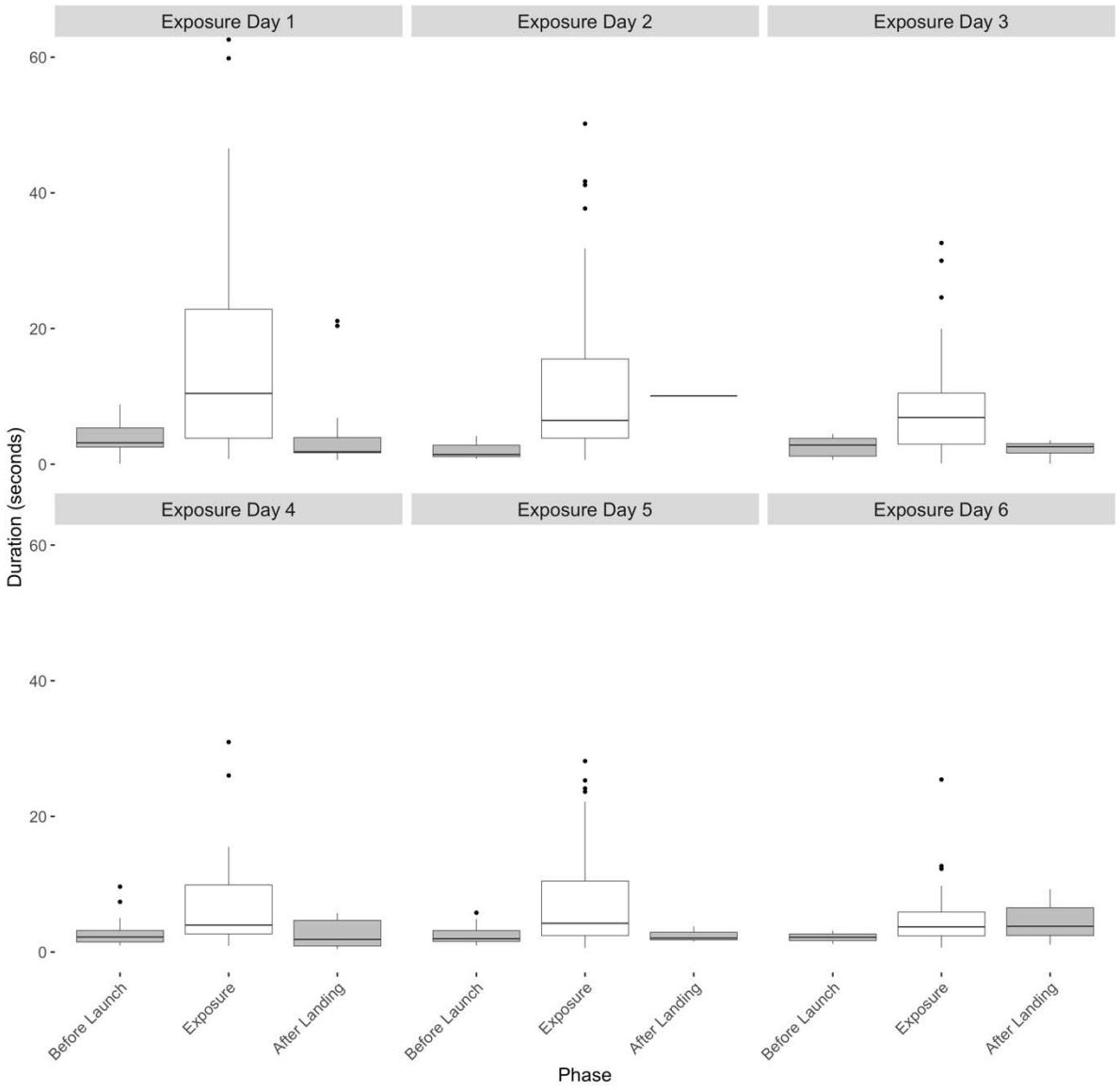
Supplementary Figure 6: The duration of the behavior "VO feeding" measured in seconds (range: 60 s) within the three different phases "before launch" ; "exposure phase" and "after landing phase", there are in total six different exposure days where the artificial predator (Robot Falcon) has been used. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase:** Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Individuals spent significantly more time feeding during the before launch phase (Estimate: 0.39 ± 0.15, p = 0.001) and after landing (Estimate: 0.82 ± 0.12, p = < 0.001) compared to the exposure phase.



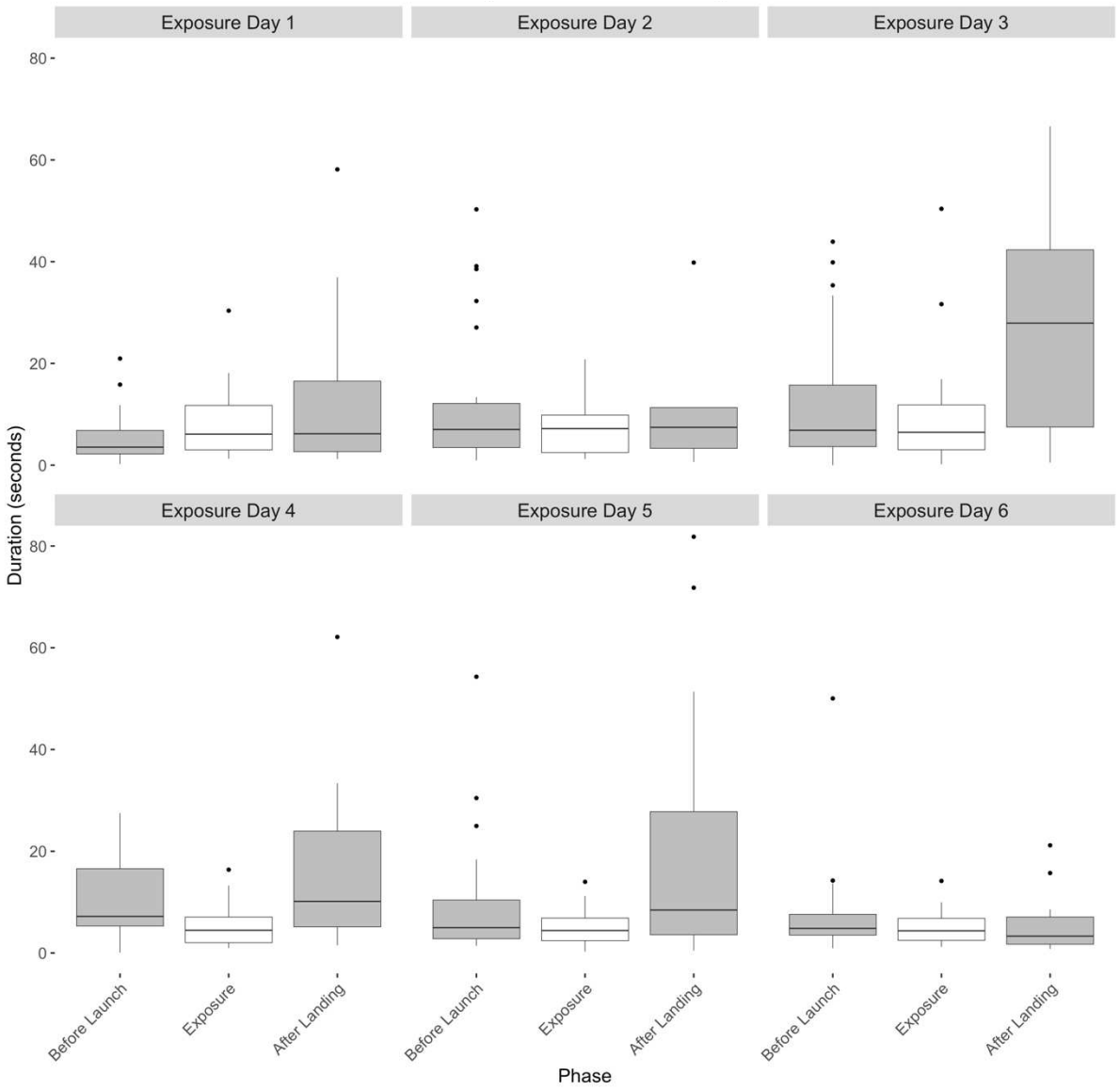
Supplementary Figure 7: The duration of the behavior “V1 short neck” measured in seconds (range: 60 s) within the three different phases “before launch” ; “exposure phase” and “after landing phase”, there are in total six different exposure days where the artificial predator (Robot Falcon) has been utilized. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase:** Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Short neck duration was significantly lower during the before launch phase (Estimate: -0.18 ± 0.09, p = 0.047), but not within the after landing phase (Estimate: -0.17 ± 0.10, p = 0.085) compared to the exposure phase.



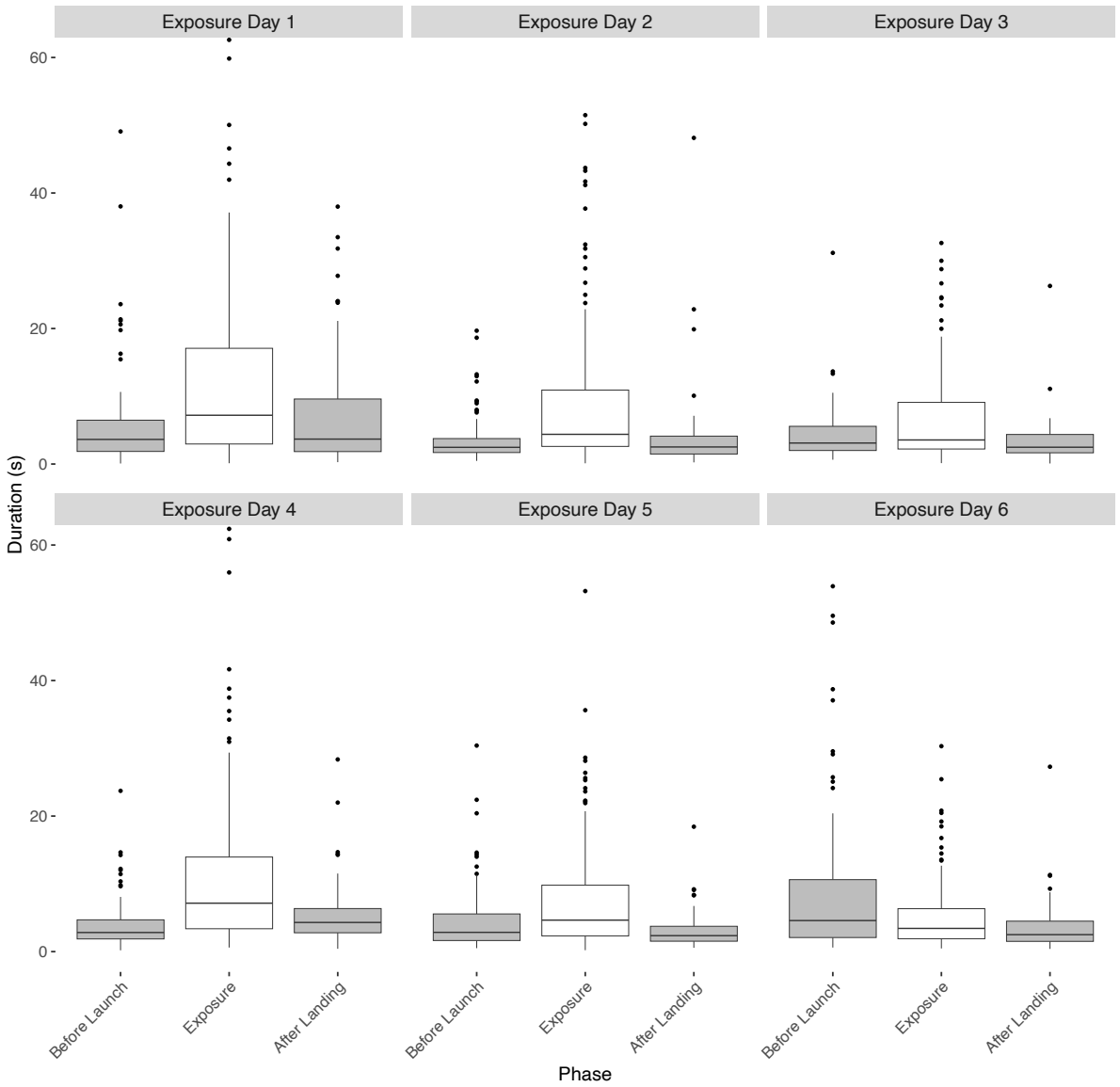
Supplementary Figure 8: The duration of the behavior "V2 long-neck" measured in seconds (range: 60 s) within the three different phases "before launch"; "exposure phase" and "after landing phase", there are in total six different exposure days where the artificial predator (Robot Falcon) has been utilized. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase:** Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Long neck showed no overall significant differences in the before launch phase (Estimate: -0.79 ± 0.48, p = 0.109) and the after landing phase (Estimate: -0.26 ± 0.31, p = 0.402) compared to the exposure phase.



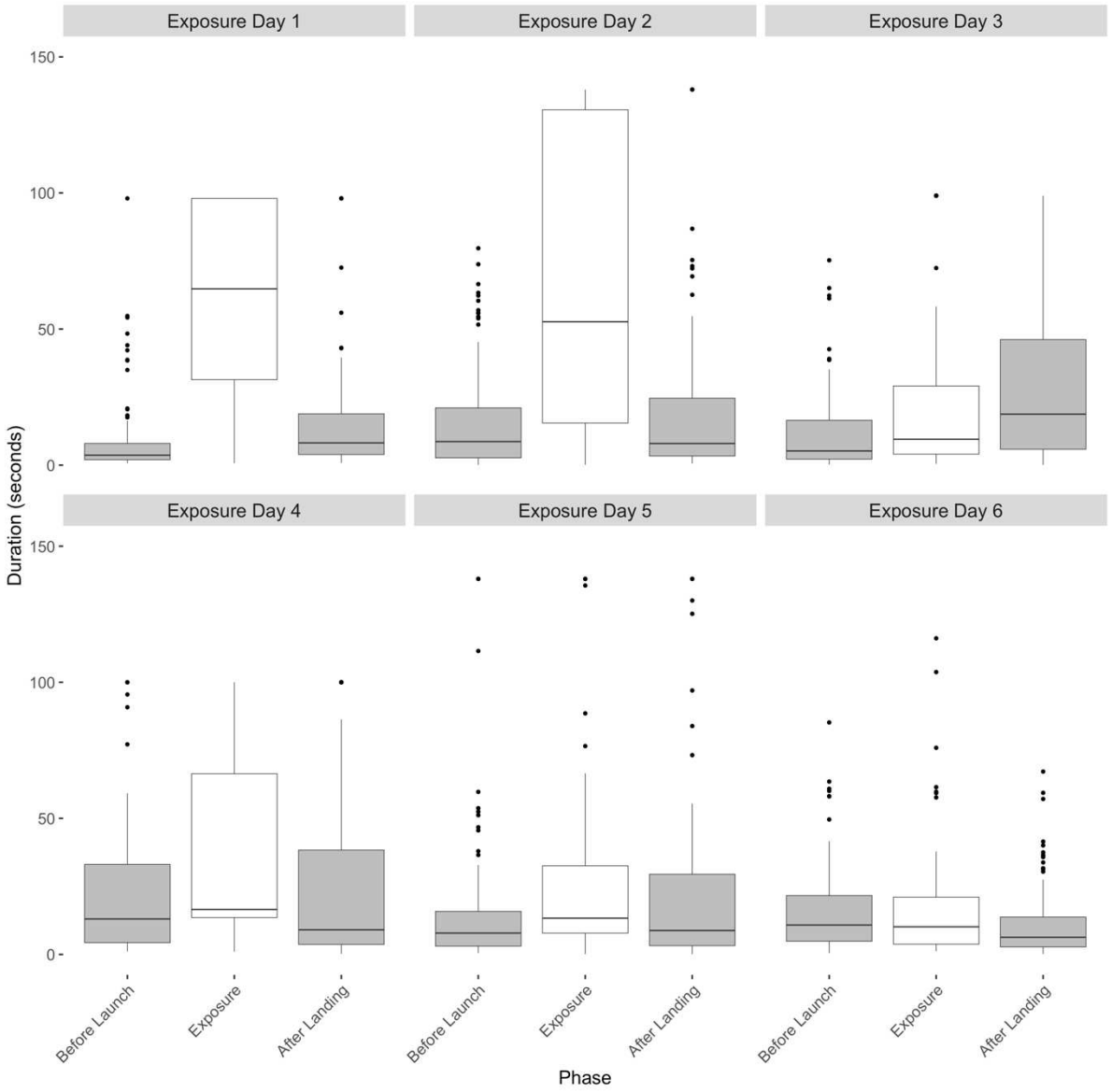
Supplementary Figure 9: The duration of the behavior "V3 one-eye-up" measured in seconds (range: 60 s) within the three different phases "before launch"; "exposure phase" and "after landing phase", there are in total six different exposure days where the artificial predator (Robot Falcon) has been utilized. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase:** Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Before launch showed a significant decrease of the V3 one-eye-up behavior (Estimate: -0.54 ± 0.16, p = 0.033), but the after landing phase showed no significant difference compared to the exposure phase (Estimate: -0.26 ± 0.30, p = 0.383).



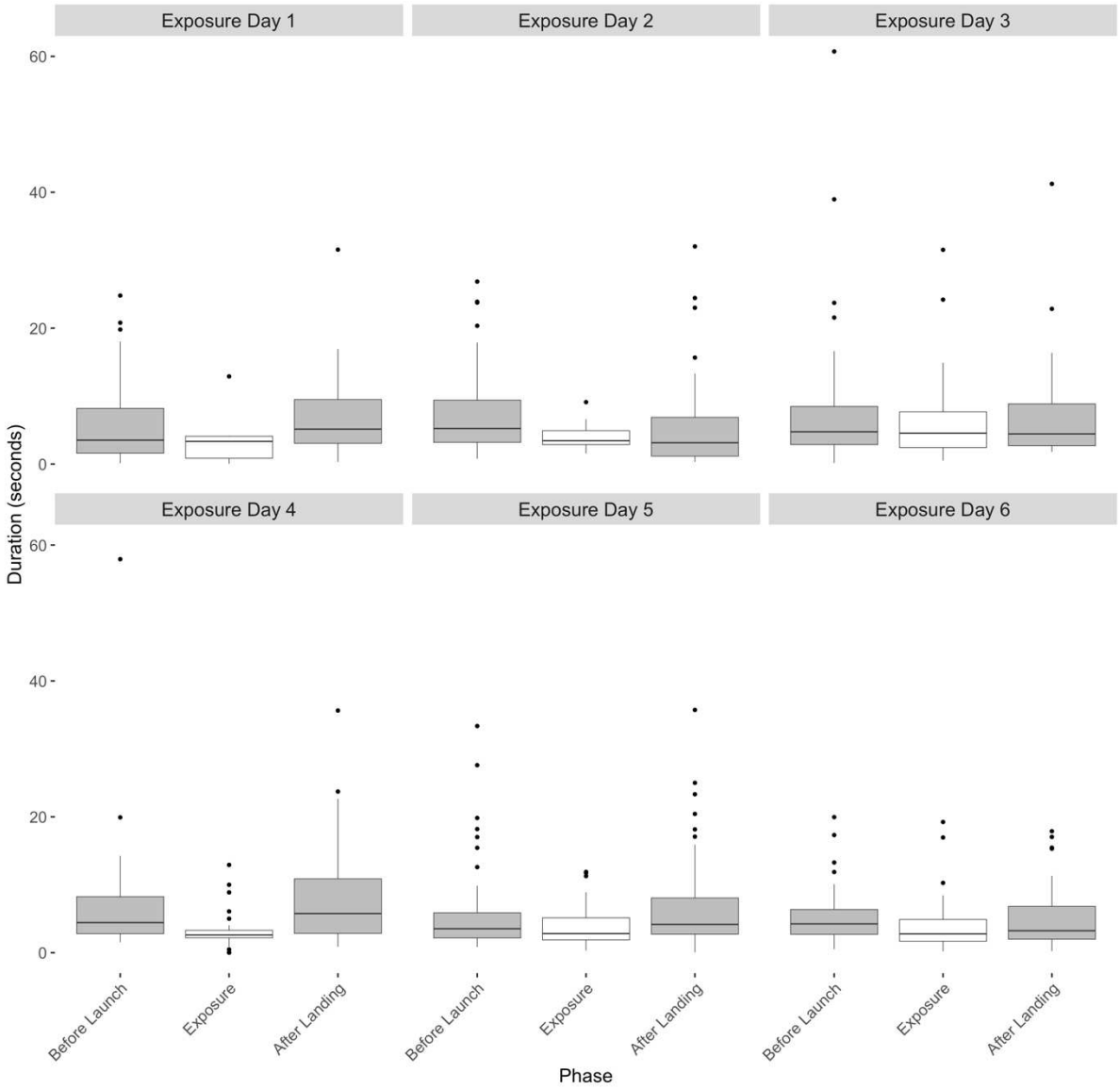
Supplementary Figure 10: The duration of the behavior "VO non-feeding" measured in seconds (range: 60 s) within the three different phases "before launch"; "exposure phase" and "after landing phase", there are in total six different exposure days where the artificial predator (Robot Falcon) has been utilized. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase:** Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. During the after landing phase there was a significant increase in non-feeding behavior (Estimate: 0.47 ± 0.10, p = < 0.001), but a non-significant difference was shown during the before launch was compared to the exposure phase (Estimate: 0.12 ± 0.10, p = 0.235).



Supplementary Figure 11: The duration of the overall "vigilance" behavior (V1 short neck, V2 long neck and V3 one-eye-up) measured in seconds (range: 60 s) within the three different phases "before launch"; "exposure phase" and "after landing phase", there are in total six different exposure days where the artificial predator (Robot Falcon) has been utilized. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase:** Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Overall, during the before launch phase, the vigilance behavior was lower compared to the exposure phase with a significant p-value (Estimate: -0.49 ± 0.14, p = 0.001), but after landing showed no significance in reference to the exposure phase (Estimate: -0.08 ± 0.18, p = 0.652)



Supplementary Figure 12: The duration of the movement "standing" measured in seconds (range: 60 s) within the three different phases "before launch" ; "exposure phase" and "after landing phase", there are in total six different exposure days where the artificial predator (Robot Falcon) has been utilized. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase:** Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. The standing behavior was significantly lower during the before launch phase (Estimate: -0.34 ± 0.04, p = < 0.001), and the after landing phase (Estimate: -0.24 ± 0.04, p = < 0.001), compared to the exposure phase.



Supplementary Figure 13: The duration of the movement "walking" measured in seconds (range: 60 s) within the three different phases "before launch" ; "exposure phase" and "after landing phase", there are in total six different exposure days where the artificial predator (Robot Falcon) has been utilized. **Before launch** defines the baseline phase without the artificial Predator (Robot Falcon), **Exposure phase:** Robot Falcon launches and hovers above the flock and the subsequent **After Landing Phase** describes the withdrawn and the landing time of the Falcon. Overall, the walking movement showed a significant increase during the before launch phase (Estimate: 0.17 ± 0.03, p = < 0.001), and the after landing phase (Estimate: 0.16 ± 0.04, p = < 0.001), compared to the exposure phase.