



# MASTERARBEIT | MASTER'S THESIS

Titel | Title

Testing the Waters - Comparing Weight Perception in Kea  
(Nestor notabilis), Ravens (Corvus corax) and Crows (Corvus  
corone/cornix)

verfasst von | submitted by  
Anna Elisa Kempf 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:

Univ.-Prof. Mag. Dr. Thomas Bugnyar

*This page is intentionally left blank*

## Table of Contents

Abstract (EN) .....	4
INTRODUCTION .....	5
Dealing with novelty .....	5
Weight as an especially interesting object property .....	6
Inferring Weight .....	6
Differences in inferential reasoning in kea and corvids .....	7
Impacts of neotic style on information use in kea and corvids .....	8
Why these differences may affect weight perception .....	9
METHODS .....	10
Subjects .....	10
Weight discrimination training .....	11
Testing sessions .....	12
Cues inherent to the objects – size and volume .....	13
Cues inherent to the context of the object – Water and Seesaw .....	13
Habituation Sessions .....	13
Statistical Analysis .....	14
RESULTS .....	16
Weight Discrimination Training .....	16
Kea visual information use (H1) .....	17
Corvid visual information use (H1) .....	19
Species Comparison of visual information use (H2) .....	19
Tactile information use in kea and corvids (H3) .....	21
Side biases & object biases .....	21
Exploration behaviors during Habituation Sessions .....	23
Exploratory Analyses .....	25
DISCUSSION .....	26
Training – learning to use a tactile cue .....	26
Visual information use depending on context .....	27
Object biases .....	29
Visual information use between species groups .....	29
Tactile Information use during test sessions .....	30
Exploration and Neotic style differences .....	31
Conclusion & Outlook .....	31
REFERENCES .....	33
Abstract (DE) .....	51

## Acknowledgements

First, I would like to thank Megan Lambert for supervision and her amazing support throughout the whole study. Thank you so much for your everlasting positive energy, all your helpful advice and the groundwork you laid so this study could happen! Second, I would like to also thank Thomas Bugnyar for his supervision and continuous support. Thank you for being so open to my ideas and the opportunities you provide for them to grow into projects! Also, I would like to thank my colleagues from the Kea lab for training most of the Kea (Elizabeth, Tessa, and David) and scientific discussions during lunch breaks at Haidlhof (David & Lu). I would also like to thank the Haidlhof animal keepers (Florian Vogel, Julius Lindenbauer, Felix Wiesinger) for the amazing care they are taking of the birds and Andras Peter for his technical support and building part of the setup. A huge thank you also goes to the people who were with me at Haidlhof (Anna & Valentine) and/or at the UBB (Awani, Lisa, Morgan, Julia, Myrto, Erica, Aylül) – you are more friends than colleagues at this point! Thank you for making every single lunch break fun and being there for me with research or life advice (or pizza). Also, a huge thank you to Timo for his emotional support and helping me with R when needed. I would also like to thank my parents for their continuous love and support throughout my studies. Special thanks go to my father for building the first version of the seesaws with me, and to my mother who helped me to pick out the right wood. Lastly I want to thank all the birds for always cheering me up with their antics – be it falling asleep perched on my shoe or forcefully putting objects into my hands (the crows), making me fear for my fingers during breeding season (the ravens) or trying to convince me to play at every chance (the Kea).

## Abstract (EN)

Humans have a sophisticated understanding of weight as a property that is inherent to all objects. Results from nonhuman animals such as chimpanzees and kea parrots suggest nonhuman animals can only perceive weight through direct experience. However, New Caledonian crows have been able to infer weight based on an objects' movement in a breeze whereas kea don't seem to make the same inference. Ecological differences between corvids and kea parrots imply the neophilic kea may rely heavily on tactile experience whereas the neophobic corvids may also use visual cues to gather information about their physical environment, which may influence weight perception.

To test this, I present common ravens (*Corvus corax*), hooded /carrion crow hybrids (*Corvus cornix/corone*) and kea parrots (*Nestor notabilis*) with four different weight discrimination tasks to tease apart differences in exploration strategies and obtain a comparative measure for weight discrimination. I also examine preferences to use visual information to infer the weight of objects based on environmental cues and cues inherent to objects themselves. Results suggest that all species rely predominantly on the more reliable tactile information to discriminate between objects. However, corvids may have a preference for using visual information in the first trial while objects are still novel. Overall, more data from the corvids would be needed.

## INTRODUCTION

Acquiring and using information about relevant environmental properties is an essential skill for many species, as it reduces ecological uncertainty, which helps to find suitable mates, avoid danger, and guides foraging decisions (Dall et al., 2005). The most basic information is processed in core knowledge systems, that are each specialized on object properties, numbers (Spelke, 2000) and geometry (Spelke, 2010), as well as agents and their actions in space (Spelke & Kinzler, 2007). These systems seem to be universal, and thus are not only assumed to exist in humans (Spelke & Kinzler, 2007), but also nonhuman primates and birds (Vallortigara, 2012). Most likely, they are already developed at birth. When imprinting on artificial objects, precocial chicks already attend to object properties such as size without any previous experience with said objects (Vallortigara et al., 2012). Beyond this basic information, what stimuli animals attend to and how they then use this information may vary based on the relevance of a stimulus to the animal. Humans, nonhuman primates and birds alike will selectively adjust their attention towards ecologically relevant information (Krauzlis et al., 2018). For example, peafowl will look longer at a taxidermied fox (Yorzinski & Platt, 2014), or a potential mate (Yorzinski et al., 2013) than predicted by chance. Some scholars have taken this thought even further, such that a species' ecological niche strongly influences its perception (Wagman et al., 2019). In this framework, perception provides awareness of opportunities to perform goal-directed behaviors ("Affordances"), rather than an objective representation of environmental features (Chemero, 2018; Turvey, 2019).

### Dealing with novelty

When environmental stimuli are novel, an animal may experience both a benefit from gaining valuable information, and a risk associated with exploration (Dall et al., 2005). This ecological trade-off manifests behaviorally as attraction to novelty ("Neophilia") and its avoidance ("Neophobia") (Corey, 1978; Barnett, 1958; Greenberg & Mettke-Hofmann, 2001; Griffin & Guez, 2014). However, neophilia and neophobia may be controlled by different mechanisms (Greenberg & Mettke-Hoffmann, 2001), and thus should be seen as separate traits rather than two opposite responses on the same scale. Neophilia levels might be influenced by feeding ecology and habitat complexity, whereas neophobia arises depending on riskiness of foraging and interspecific competition (Greenberg & Mettke-Hoffmann, 2001, Greenberg, 2003). This is why a species' unique combination of neophilia and neophobia is summed up as "Neotic style" (O'Hara et al., 2017).

A species' neotic style has been shown to influence the timing of explorative behaviors, with more neophobic individuals exploring not less overall, but later, once habituated to a task (O'Hara et al., 2017). Thus, a species' neotic style modulates exploration behaviors, and may also affect the ways animals gather and use information about their environment, and the properties of objects within it (Auersperg et al., 2011, Greenberg, 2003).

### Weight as an especially interesting object property

One interesting object property is the weight of objects and food items, because unlike many other properties it cannot be seen, and therefore only experienced directly through proprioceptive feedback. Weight can be a relevant cue for nonhuman animals when selecting nuts and seeds (Langen, 1999; Jablonski et al., 2015; Heinrich et al., 1997; Visalberghi et al., 2003) and further selecting functional tools to open them (Schrauf et al., 2008). A species' ability to attend to the weight of an object is often measured via the weight discrimination task, where animals are trained to discriminate between visually identical objects of different weights. Surprisingly, this seems to be difficult for primates and apes. Chimpanzees (*Pan troglodytes*) need several hundred trials (Schrauf & Call, 2009; McCulloch, 1941; Povinelli 2012) to consistently discriminate objects based on their weight alone. Birds can learn to do this faster - Goffins cockatoos (*Cacatua goffiniana*) need approximately 60 trials on average (Lambert et al., 2021), and Kea parrots (*Nestor notabilis*) around 35 trials (Temeroli et al., 2024). During nestbuilding, objects of different shapes and weights need to be transported in flight, which is an energetically costly activity for birds (Mainwaring et al., 2013). This intense period of transporting various objects may necessitate an embodied representation of object weight while handling (Povinelli, 2012), making birds promising candidates for weight studies.

### Inferring Weight

Though it cannot be seen, weight can also be inferred through auditory or visual cues which can either be inherent to the object itself – e.g. size or volume, or observable through their interaction with other objects – e.g. heavy sinking objects or light floating objects.

Specifically, the weight of an object can be represented even without the proprioceptive feedback necessary to directly experience it. Human children are able to infer the weight of objects through observation by age five (Kaiser & Proffitt, 1984). In a series of studies, Povinelli and colleagues found nonhuman primates have difficulties in various tasks testing a

more complex understanding of weight as an object property. Chimpanzees preemptively assess the effort needed to lift an object using its size but not auditory or texture cues (Povinelli, 2012). Furthermore, they cannot infer the weight of a box after observing human experimenters or conspecifics trying to lift it, and are at chance level when selecting an either light or heavy object to dislodge an apple (Povinelli 2012). Studies from other research groups provide a more mixed picture. For example, capuchins seem to infer weight based on size and material (Visalberghi et al., 2009). Furthermore, chimpanzees are able to infer the weight of a food reward based on its position on a seesaw (Hanus & Call., 2008, but see Povinelli, 2012). Weight inference has also been studied in birds. New Caledonian crows (*Corvus moneduloides*) can discriminate between two novel objects moving in a breeze (Jelbert et al., 2019, but see Henley, 2020), but kea don't appear to make this inference (Temeroli et al., 2024). Notably, results pointing towards weight inference abilities from both primates and birds are still subject to debate (Birds: Henley, 2020; Primates: Povinelli, 2012). Povinelli and colleagues remain convinced that a more sophisticated understanding of weight is limited to humans (Povinelli, 2012). However, the variation in results described above highlights the importance of investigating weight inference abilities depending on a species' ecology, its exploration strategy and the specific cues nonhuman animals may use to infer the weight of objects.

### Differences in inferential reasoning in kea and corvids

Species dependent differences in the perception of weight between Kea parrots and a corvid potentially coincide with differences in inferential reasoning and exploration strategies. In general, both parrots and corvids have been said to have evolved similar cognitive capacities independently (Osvath et al., 2014). Additionally, both kea (O'Hara et al, 2016), common ravens (*Corvus corax*; Schloegl et al., 2009) and carrion crows (*Corvus corone*; Mikolasch et al., 2012) have shown to be capable of inferential reasoning, although this may be a particularly adaptive skill for food caching species such as corvids (Schloegl, 2009, Mikolasch et al., 2012, as reviewed in Lambert et al., 2019). In a study that directly compared inferential reasoning between Common ravens and kea parrots (Schloegl et al., 2009), ravens used inferential reasoning more readily to limit their effort when searching for food hidden in two hollow tubes and under containers, whereas kea spend more time interacting with the tubes directly. This finding is consistent with differences in exploration strategies and information use between kea and corvids.



## Impacts of neotic style on information use in kea and corvids

Parrots and corvids also differ in neotic style. Although both parrots and corvids include many species that are generalist foragers and live in variable environments (Emery, 2006; reviewed in Lambert et al., 2019), corvids display neophobia (Heinrich, Marzluff & Adams, 1995; Miller et al., 2022) in combination with temporally dependent neophilia (Heinrich, 1995), whereas specifically kea are notoriously neophilic with low neophobia (Huber & Gajdon, 2006).

Kea naturally live in a variable, low risk environment (Huber & Gajdon, 2006) and display a high drive and desire to directly manipulate and explore objects. They may have developed a haptic exploration strategy (Auersperg et al., 2011, Lambert et al., 2019), and can use information gained during exploration to solve physical problems (Lambert et al., 2017). In doing so, they may rely on explorative trial and error (reviewed in Lambert et al., 2019). It has been suggested that this tendency toward direct interaction may limit the ability and readiness to use visual information to solve cognitive tasks in highly explorative species (Schloegl et al., 2009). However, it is also possible that the kea's explorative nature in combination with little inhibitory control (Schwing, 2017) leads to difficulties when measuring such reasoning skills (reviewed in Lambert et al., 2019).

Corvids on the other hand, specifically New Caledonian crows, have been described as visual and strategic explorers due to their neophobia (Auersperg et al., 2011, Lambert et al., 2019). This preference for using visual information may also extend to other corvid species. Both ravens and carrion crows are scavengers which exposes them to relatively high predation risk (Heinrich, 2014; Heinrich, 1988), so they may also experience a higher subjective risk associated with interacting with novel objects. Carrion crows show object neophobia levels similar to New Caledonian crows, whereas common ravens are even more neophobic towards objects than both aforementioned crow species (Miller et al., 2022). Carrion crows have performed similarly on reversal learning and a novel box-opening task to New Caledonian crows (Teschke et al., 2013), which suggests similar physical cognitive abilities independent of tool use (reviewed in Lambert et al., 2019). Furthermore, ravens have performed comparably to great apes in cognitive tasks requiring visual information use (Pika et al., 2020). This could indicate a more visually oriented rather than haptic exploration strategy across the genus *corvus*.

## Why these differences may affect weight perception

Taken together, differences in weight inference abilities between kea and New Caledonian crows may stem from variation in exploration strategies. Because of their neophobia, corvids may experience a subjective risk when touching novel objects and thus may attend to visual cues to infer object weight, whereas the neophilic kea don't experience this risk and will forego visual cues to object weight and immediately use tactile information. Furthermore, whether these cues are within the objects themselves or observable through their interaction with other structures may influence the birds' use of visual information.

**To clarify the role of ecological factors and context, this study addressed the following research questions:**

- 1. Do kea and corvids use different initial strategies to gather information about object properties such as weight?**
- 2. Which visual cues may be used or not used by the subjects?**

To answer these questions, kea parrots, common ravens and hooded crow / carrion crow hybrids were compared across 4 different two-choice tasks varying in the available cues to object weight. After being trained to return either a "light" or "heavy" target object to the experimenter, birds were given the following test conditions: size, volume, as well as seeing the test objects on a seesaw and floating or sinking in a water bowl. Visual cues to object weight were available but not essential for solving each task.

**The following hypotheses (H) and predictions (P) were tested:**

**H1: Visual information use is affected by the specific cue to object weight.**

P1.: The subjects' use of visual cues differs between test conditions.

**H2: Compared to kea, corvids rely more heavily on visual information to distinguish between objects of different weights.**

P3: Corvids touch the target object first more frequently than the kea, whereas the kea will first contact the target object at random.

**H3: Both corvids (ravens and crows) and kea are able to use tactile information to distinguish between objects of different weights.**

P2: After interacting with the test objects, subjects return the correct target object irrespective of their species.

Furthermore, differences in weight discrimination during the training stage between kea and corvids as well as exploration behaviors of both corvids and kea during habituation to the tests are described. As an exploratory analysis, relationships between kea's exploration behaviors during habituation and visual information use during testing are examined.

## METHODS

### Subjects

20 kea (8f, 12m), 3 ravens (2f, 1m) and 6 crows (2f, 4m) were selected to participate in the study. Data collection took place between December 2023 to August 2024.

All subjects were housed at Haidlhof research station (Bad Vöslau, AT) in social groups with conspecifics, in enriched enclosures including natural and human-made objects to manipulate as well as access to water ad libitum. Both the corvids and the kea had water pools in their enclosures. Furthermore, the kea had wooden seesaws in their enclosures prior to the study whereas the corvids did not. Because of this difference, wooden seesaws similar to the testing seesaws were put into the corvid enclosures 6 weeks before the start of data collection. To not introduce a bias because the corvid seesaws were more similar to the ones used during testing, the kea also were habituated to these seesaws but only for two weeks before the start of data collection.

First, each bird was trained on weight discrimination. 17 of the Kea were already trained (Temeroli et al., 2024). 3 more kea were trained in addition for this study. 3 crows and 1 Raven did not pass the training, and 1 crow dropped out due to illness, leaving 20 kea, 2 ravens, and 2 crows for testing.

*Table 1: Overview of all subjects that participated in the study. Subjects with a \* dropped out before testing started. Age is in years at time of testing.*

<b>Subject Name</b>	<b>Species</b>	<b>Species Group</b>	<b>Sex</b>	<b>Parent / Hand-reared</b>	<b>Age (Y)</b>
Rocky	Raven	Corvid	m	hand-reared	12
Nobel*	Raven	Corvid	f	hand-reared	12
Astrid	Raven	Corvid	f	hand-reared	14
Corbie	Hooded crow	Corvid	m	hand-reared	12
Daisy	Hooded crow	Corvid	f	hand-reared	12
Walter*	Carrion crow	Corvid	m	hand-reared	13
Signore*	Carrion crow	Corvid	m	hand-reared	12
Peppi*	Carrion crow	Corvid	f	hand-reared	12
Saul*	Hooded crow	Corvid	m	hand-reared	12
Odo	Kea	Kea	m	parent-reared	9
Fay	Kea	Kea	f	parent-reared	8
Willy	Kea	Kea	f	hand-reared	17
Kiri	Kea	Kea	f	parent-reared	9
John	Kea	Kea	m	parent-reared	25
Jean-Luc	Kea	Kea	m	hand-reared	9
Ponga	Kea	Kea	m	hand-reared	2
Fluff	Kea	Kea	f	hand-reared	2
Kermit	Kea	Kea	m	hand-reared	20
Paul	Kea	Kea	m	hand-reared	14
Tai	Kea	Kea	f	parent-reared	6
Frowin	Kea	Kea	m	parent-reared	20
Diana	Kea	Kea	f	hand-reared	7
Anu	Kea	Kea	m	hand-reared	17
Skipper	Kea	Kea	m	hand-reared	7
Pancake	Kea	Kea	m	hand-reared	7
Mali	Kea	Kea	f	parent-reared	10
Pick	Kea	Kea	m	hand-reared	20
Roku	Kea	Kea	m	parent-reared	16
Sunny	Kea	Kea	f	hand-reared	17

## Weight discrimination training

The training procedure was adapted from Temeroli et al., 2024.

Birds were split into two groups, a “light” and a “heavy” group, and assigned a “light” 16g object or a “heavy” 116g object as a target, respectively. Crow target weights were adjusted to accommodate their smaller body size (65g “heavy”, 10g “light”). These object weights

were chosen so that the heavy object corresponded to about 10% of the average body weight of each species. This ensured that a substantial effort was needed to lift them, and thus the objects were clearly distinguishable by their weight for the animal. Objects were made from polymer clay with nontoxic fishing weights inside, to be as visually indistinguishable as possible.

In the first training session, each bird was given only the object with their target weight, and asked to return it in exchange for a treat multiple times. The kea were trained to drop the object in a wooden box, the corvids to return the object to the experimenter. This was because both groups were already trained on to their respective way of exchanging the test objects before the beginning of this study.

Each subsequent training session consisted of 10 trials, where the subjects were given both objects (side of the target object pseudorandomized) and asked to select their target object. Subjects had passed the training when successfully selecting the correct object 8 out of 10 times within a session, for three consecutive sessions. Here, subjects were allowed to manipulate and explore both test objects before returning the object with their target weight.

### Testing sessions

After passing the weight discrimination training, subjects received 4 different test conditions (size, volume, water bowl and seesaw) where visual cues to object weight were available. The “light” and “heavy” object weight was kept consistent, and was the same as the weight of training objects. Each bird received one test session of each condition in a randomized order. Each test session consisted of 5 trials, where an object pair was presented and again birds had to select the object with their respective target weight. Again, birds were allowed to touch and explore both objects but could only exchange one. The birds’ use of visual information was measured through the object the birds contacted first (“First Choice”) and the bird’s use of tactile information through the object that was exchanged (“Final Choice”).

## Cues inherent to the objects – size and volume

Two of the conditions had visual cues to object weight inherent to the objects themselves. In the size condition, birds were given a big “heavy” object and a small “light” object (Figure 1). In the volume condition, birds were given a ring-shaped “light” object and a circular “heavy” object (Figure 2).



Figure 1: Objects used in the size condition.. L: heavy object, 116g. R: light object, 16g.



Figure 2: Objects used in the volume condition. L: heavy object, 116g. R: light object, 16g.

## Cues inherent to the context of the object – Water and Seesaw

The other two conditions, the visual cues to object weight were available in the environmental context the objects were presented in. For the water bowl condition, the subjects were presented with two water bowls with a floating “light” object and a sinking “heavy” object inside (Figure 3). For the Seesaw condition, the objects were presented on a wooden seesaw with the “light” object being on the top and the “heavy” object on the bottom (Figure 4).

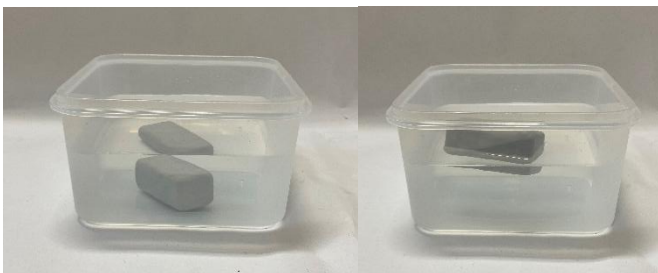


Figure 3: Setup of the waterbowl condition. L: heavy object, 116g. R: light object, 16g



Figure 4: Setup of the seesaw condition. R: heavy object, 116g. L: light object, 16g.

## Habituation Sessions

To familiarize individuals with the context of the tests, they received controlled previous experience with the water bowls and the seesaw (habituation sessions) without the test objects present in the setup. This was done to ensure a similar experience of all subjects before testing, since kea had both pools and seesaws already in their enclosures but the corvids only had water and no seesaws.

In the seesaw habituation session, two cups with 50g fishing weights (20g for the crows) were placed on top of the seesaw, with a treat hidden underneath. This intermediate weight was chosen specifically so that birds did experience weight as a significant factor during the session, but would not associate it with their respective target weight. For 10 trials, birds had to remove the cups to get to both treats, to learn the way the seesaw behaves when light and heavy objects interact with it.

In the water bowl habituation session, birds were given one of the bowls filled halfway with water. Inside, two wood chips and two stones (each baited with peanut butter) were placed. Birds were able to manipulate all objects and forage until all peanut butter was eaten or a maximum of 10 minutes was reached. Ideally, here subjects were able to experience that heavy objects sink in water in the case of the stones and light objects float in the case of the wood chips.

For both sessions, birds were encouraged to keep exploring by the experimenter if they stopped exploring before all food was eaten to ensure a comparable experience. Sessions were filmed and various object exploration behaviors as well as experimenter encouragement were coded using the software BORIS (Friard & Gamba, 2016). Detailed ethograms of all behaviors coded can be found in the appendix (A.1 & A.2).

### Statistical Analysis

To investigate the influence of test condition on the subjects' information use, Generalized Linear Mixed Models (GLMM; Baayen 2008) with binomial error structure and logit link function were used. Included were test condition, target weight, species group and sex as fixed effects and individual ID as random effects. The latter was mainly included to account for repeated measures of each subject.

During analysis of visual information use (H1 and H2), models were run first on the data only from the first trial, and afterwards on the data from all trials. The first choice of the first trial was prioritized as an outcome variable because it takes place before birds can get haptic feedback about the weight of the test objects. This measure therefore would provide the strongest evidence for weight inference.

All models were then compared with their respective null models lacking the fixed effects but with the same random effects structure as the full models (Forstmeier and Schielzeth, 2011) using a likelihood ratio test (Dobson, 2002).

As there was very little data from the corvids only, the first two models were fitted only on the Kea data to investigate the influence of test condition and target weight on first choice (H1):

- **M1:** First Choice (First Trial)  $\sim$  Test Condition + Target Weight + Sex + (1|ID)
- **M2:** First Choice (all Trials)  $\sim$  Test Condition \* Target Weight + Sex + Trial Number + (1|ID)

Two similar models were fitted on the full data set to compare visual information use between the species (H2). Here species group was included as a fixed effect:

- **M3:** First Choice (First Trial)  $\sim$  Species Group + Test Condition + Target Weight + Sex + (1|ID)
- **M4:** First Choice (all Trials)  $\sim$  Species Group + Test Condition + Target Weight + Sex + Trial Number + (1|ID)

To assess how well both species can use tactile information to return their target object (H3) three more models with the Final Choice as an outcome variable were fitted. First, both kea and corvids were analyzed separately to compare their performance to chance (M5 & M6). After, a model including Species Group as a fixed effect was fitted on the whole dataset to compare their performance.

- **M5:** Final Choice (Kea only)  $\sim$  1 + (1|ID)
- **M6:** Final Choice (Corvids only)  $\sim$  1 + (1|ID)
- **M7:** Final Choice (all)  $\sim$  Species Group + (1|ID)

Lastly, two more exploratory generalized linear models (GLM) with binomial error distribution and logit link function were fitted to test whether exploration during the habituation sessions influenced the kea use of visual information in the first trial of the respective test. As some birds didn't participate every day, the number of days between the habituation session and the testing session was included as a control variable. During the seesaw habituation session, combinatory object play was coded when birds put the cups on the seesaw and thus could experience the influence of a weighted object on the movement



of the seesaw. As this could also improve their learning, combinatory object play was additionally included as a predictor variable:

- **M8:** First Choice (First Trial Waterbowl) ~ duration object manipulation + days to test + Target Weight
- **M9:** First Choice (First Trial Seesaw) ~ duration object manipulation + combinatory object play + days to test + Target Weight

All models were fitted in R (R Core Team, 2021), using the functions `glmer` (GLMM) and `glm` (GLM) of R package “lme4” (Bates et al., 2015). Model assumptions were checked through visual inspection of the plotted outliers and plotted binned residuals using the R package “see” (Lüdtke et al., 2021). Additionally, all models were tested for overdispersion using a custom function by Ben Bolker and colleagues (2024; see appendix A.3). All graphs were made in R using the `ggplot2` package (Wickham, 2016). Data manipulation was done using the tidyverse in R (Wickham, 2019). The script for the main analyses can be found in the appendix (A.3), not including data manipulation or graphs.

Side and object biases were assessed descriptively, as well as exploration behaviors during habituation sessions. The latency to contact the test objects during these habituation sessions was also measured, to roughly describe differences in neotic responses towards the test setup.

## RESULTS

### Weight Discrimination Training

On average, both crows ( $SD_{\text{crows}} = 2.65$ ,  $M_{\text{crows}} = 6$ ,  $n_{\text{crows}} = 3$ ) and ravens ( $SD_{\text{ravens}} = 3.60$ ,  $M_{\text{ravens}} = 7$ ,  $n_{\text{ravens}} = 3$ ) took more sessions to reach the weight discrimination criterion than the Kea ( $SD_{\text{kea}} = 1.0$ ,  $M_{\text{kea}} = 5$ ,  $n_{\text{kea}} = 3$ ). However, both crows ( $\sigma^2_{\text{crows}} = 7$ ) and ravens ( $\sigma^2_{\text{ravens}} = 13$ ) had higher within-group variances compared to the kea ( $\sigma^2_{\text{kea}} = 1$ ). One crow (Walter) and one raven (Rocky) passed faster than all kea that were trained in this study, however most of the Kea trained previously did also pass in 30 trials or less (Temeroli et al., 2024). On the other hand, one crow (Daisy) and one raven (Nobel) took longer to pass than all kea or never passed (in the case of Nobel, see Figure 5) the training. Unfortunately, all corvids that

were in the “heavy” group did not pass the training (Nobel) or stopped participating after 3-7 sessions (all crows).

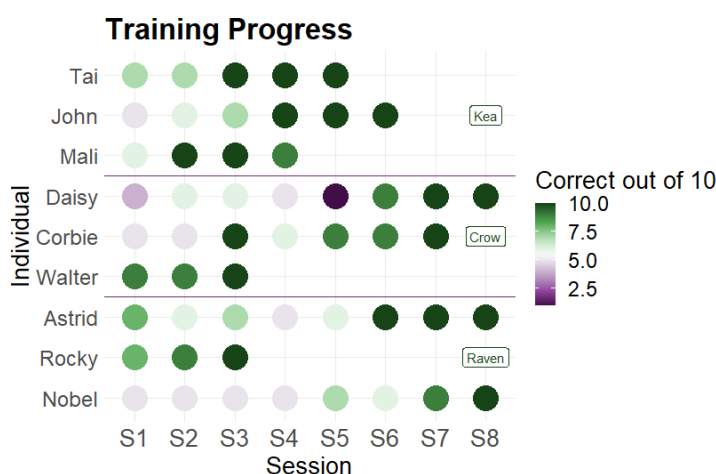


Figure 5: Training sessions of individual per session, separated by species. Color indicates the proportion of objects returned correctly out of 10.

## Kea visual information use (H1)

When predicting the first choice of keas in the first trial, a full-null model comparison revealed no significant difference ( $\chi^2 = 8.66$ ,  $df = 5$ ,  $p = 0.12$ ). However, within the full model, target weight had a significant effect on the first choice ( $\beta = -1.28$ ,  $SE = 0.48$ ,  $z = -2.65$ ,  $p = .008$ ) whereas test condition did not (see Table 2). To summarize, the test condition did not have an impact on the object the kea touched first in the first trial (Figure 6L). However, birds in the light group may have performed worse than birds in the heavy group over all conditions in the first trial (Table 2).

Table 2: Results from Model 1. Performance of kea during first trial within condition.

First Choice ~ Test Condition + Target Weight + Sex + (1   Individual)				
Term	Estimate	Std. Error	z-value	p-value
Intercept	1.286	0.634	2.03	0.042 *
Condition Size	-0.449	0.673	-0.67	0.505
Condition Volume	0.000	0.679	0.00	1.000
Condition Waterbowl	-0.449	0.673	-0.67	0.505
Target Weight light	-1.278	0.482	-2.65	0.008 **
Sex male	-0.443	0.491	-0.9	0.367

When predicting the first choice of the Kea in all trials, target weight as well as test condition and the trial number had a significant impact in comparison to a null model ( $\chi^2 = 59.72$ ,  $df = 12$ ,  $p < .001$ ), Specifically, target weight significantly interacted with volume ( $\beta = -2.47$ ,  $SE = 0.75$ ,  $z = -3.31$ ,  $p < .001$ ) and waterbowl ( $\beta = 1.31$ ,  $SE = 0.60$ ,  $z = 2.17$ ,  $p = .029$ ) conditions (see Figure 2). As single predictors, condition volume ( $\beta = 1.99$ ,  $SE = 0.60$ ,  $z = -3.31$ ,  $p < .001$ ), condition waterbowl ( $\beta = -1.21$ ,  $SE = 0.41$ ,  $z = -2.92$ ,  $p = .004$ ) and Trial Number 4 ( $\beta = 0.76$ ,  $SE = 0.36$ ,  $z = 2.11$ ,  $p = .03$ ) had an effect (Table 3; Figure 6L).

Table 3: Results from Model 2. Performance of kea in all trials within condition.

First Choice ~ Test Condition * Target Weight + Sex + Trialnumber + (1   Individual)				
Term	Estimate	Std. Error	z-value	p-value
Intercept	0.7505	0.4367	1.72	0.0857
Condition Size	0.1774	0.4211	0.42	0.673
Condition Volume	1.9976	0.6037	3.31	0.0009*
Condition Waterbowl	-1.2112	0.4149	-2.92	0.0035**
Target Weight light	-0.6703	0.4677	-1.43	0.152
Sex male	-0.3509	0.3030	-1.16	0.247
Trial 2	0.0609	0.3491	0.17	0.862
Trial 3	-0.1218	0.3489	-0.35	0.727
Trial 4	0.7613	0.3606	2.11	0.0348*
Trial 5	0.1221	0.3494	0.35	0.727
Size * light	-0.2718	0.6048	-0.45	0.653
Volume * light	-2.4747	0.7470	-3.31	0.0009***
Waterbowl * light	1.3055	0.6010	2.17	0.0298*

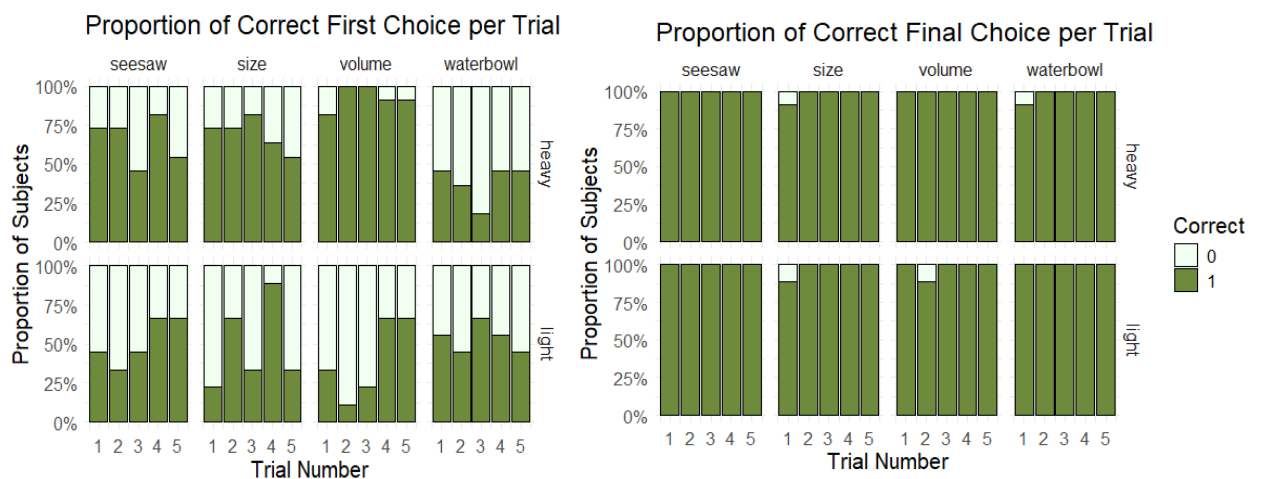


Figure 6: L: Proportion of kea visual information use over trials, separated by condition and target weight. R: Proportion tactile information use over trials, separated by condition and target weight.

## Corvid visual information use (H1)

Because some corvids dropped out during testing due to illness, and thus did not get all test conditions, the sample size from the corvid tests alone ( $n=4$ ) was insufficient to conduct reliable statistical analyses. Given this small sample size, these results should be interpreted with caution, as they may not be generalizable to a broader population.

In the first trial, more than half of the corvids first contacted their target object in 3 of the 4 conditions (volume 75% of subjects correct,  $n = 4$ ; waterbowl 75% of subjects correct,  $n = 4$ ; size 66% of subjects correct,  $n = 3$ ). In the seesaw condition, one subject first contacted their target object while the other did not (50% of subjects correct,  $n=2$ ).

However, in trial 2-5, the Corvid's first choice did not improve, thus even after learning on the first trial which object was successful, they did not use visual information to solve the task going forward (Figure 7).

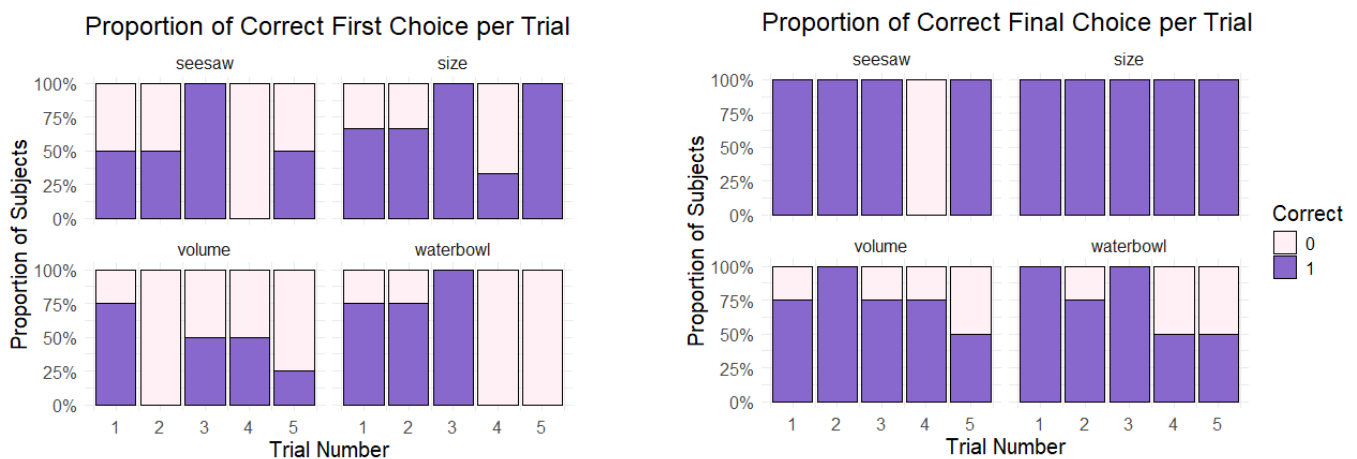


Figure 7: L: Proportion of visual information use by corvids over trials, separated by condition. R: Proportion of tactile information use by corvids over trials, separated by condition.

## Species Comparison of visual information use (H2)

When comparing how successful corvids and Kea were in touching the correct object first in the first trial, a model including all birds was not better at predicting the first choice than a null model ( $\chi^2 = 8.78$ ,  $df = 6$ ,  $p = .18$ ). However, target weight had a significant effect in the full model ( $\beta = -1.24$ ,  $SE = 0.48$ ,  $z = -2.61$ ,  $p = .009$ ) and there was a trend towards significance of species group ( $\beta = -1.26$ ,  $SE = 0.69$ ,  $z = -1.80$ ,  $p = .07$ ) (Table 4).

Table 4: Results from Model 3. Species comparison of visual information use in the first trial.

<b>First Choice ~ Species Group + Test Condition + Target Weight + Sex + (1 Individual)</b>				
Term	Estimate	Std. Error	z-value	p-value
Intercept	2.272	0.927	2.45	0.0143 *
Species Group Kea	-1.261	0.699	-1.80	0.0711 .
Condition Size	-0.320	0.632	-0.51	0.6122
Condition Volume	0.116	0.635	0.18	0.8546
Condition Waterbowl	-0.260	0.628	-0.41	0.6788
Target Weight light	-1.242	0.476	-2.61	0.0091 **
Sex male	-0.197	0.451	-0.44	0.6625

The same model including all trials was significantly better at predicting First Choice than a null model ( $\chi^2 = 19.94$ ,  $df = 7$ ,  $p = .006$ ). However, it showed no trend towards a significant effect of Species Group (Table 5), indicating that if any species difference is potentially present, it can only be observed in the first trial. Again, target weight had a significant effect ( $\beta = -0.79$ ,  $SE = 0.24$ ,  $z = -3.27$ ,  $p = .001$ ).

Table 5: Results from Model 4. Species comparison of visual information use in all trials.

<b>First Choice ~ Species Group + Test Condition + Target Weight + Sex + Trial_Nr + (1 Individual)</b>				
Term	Estimate	Std. Error	z-value	p-value
Intercept	0.9535	0.4845	1.97	0.0491 *
Species Group Kea	-0.1661	0.3367	-0.49	0.6218
Condition Size	0.1720	0.2805	0.61	0.5397
Condition Volume	0.2878	0.2793	1.03	0.3029
Condition Waterbowl	-0.4997	0.2747	-1.82	0.0690 .
Target Weight light	-0.7947	0.2431	-3.27	0.0011 **
Sex male	-0.1988	0.2276	-0.87	0.3824
Trial Nr	0.0189	0.0687	0.27	0.7835

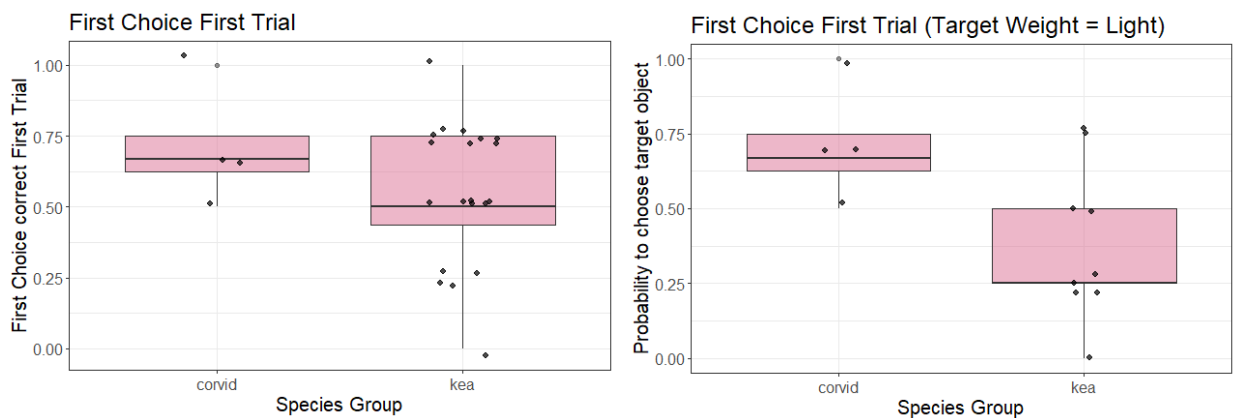


Figure 8: Species comparison of proportion of correct responses in first Trial over conditions per individual. L: both light and heavy target weight. R: Separated to only light target weight.

### Tactile information use in kea and corvids (H3)

Kea were significantly better than chance at returning their target object (Table 6,  $\beta = 5.840$ ,  $SE = 1.769$ ,  $z = 3.302$ ,  $p < .001$ ) and showed near perfect performance using tactile information (Figure 6R). Corvids were also significantly better than chance (Table 7,  $\beta = 1.608$ ,  $SE = 0.486$ ,  $z = 3.308$ ,  $p < .001$ ; Figure 7R). Again, results from the corvids need to be interpreted with caution as there are only 4 individuals present in the dataset. When comparing the final choice of corvids to the kea, species group does show a significant effect (Table 8;  $\beta = 3.1958$ ,  $SE = 0.1497$ ,  $z = 2.780$ ,  $p = .005$ ), whereas target weight and test condition do not (Table 8). This model is significantly better at predicting final choice than a null-model ( $\chi^2 = 12.32$ ,  $df = 5$ ,  $p = .031$ ).

Table 6: Results from Model 5. Kea tactile information use.

<b>Final Choice (Kea) ~ 1 + (1 ID)</b>				
Term	Estimate	Std. Error	z-value	p-value
Intercept	5.840	1.769	3.302	0.000961 ***

Table 7: Results from Model 6. Corvid tactile information use.

<b>Final Choice (Corvids) ~ 1 + (1 ID)</b>				
Term	Estimate	Std. Error	z-value	p-value
Intercept	1.608	0.486	3.308	0.000939 ***

Table 8: Results from Model 7. Tactile information use between species.

<b>Final Choice ~ Species Group + Test Condition + Target Weight + (1 Individual)</b>				
Term	Estimate	Std. Error	z-value	p-value
Intercept	2.6257	1.5247	1.722	0.0850
Species Group Kea	3.1958	1.1497	2.780	0.0054 **
Condition Size	-0.1690	1.1137	-0.152	0.8794
Condition Volume	-1.0526	0.9189	-1.145	0.2520
Condition Waterbowl	-1.0526	0.9189	-1.145	0.2520
Target Weight light	-0.1260	1.1583	-0.109	0.9134

### Side biases & object biases

Both corvids and Kea first contacted the heavier object more frequently than the light object in the volume condition irrespective of their target weight, which may suggest a bias towards

this heavy object (Figure 9). In the size condition, Kea contacted the larger, heavy object more frequently than the smaller, light object while the corvids did the opposite (Figure 10). corvids contacted both objects first the same amount of times in both the seesaw and the waterbowl condition, whereas keas had a preference for the heavy object in the seesaw and a preference for the light object in the waterbowl condition.

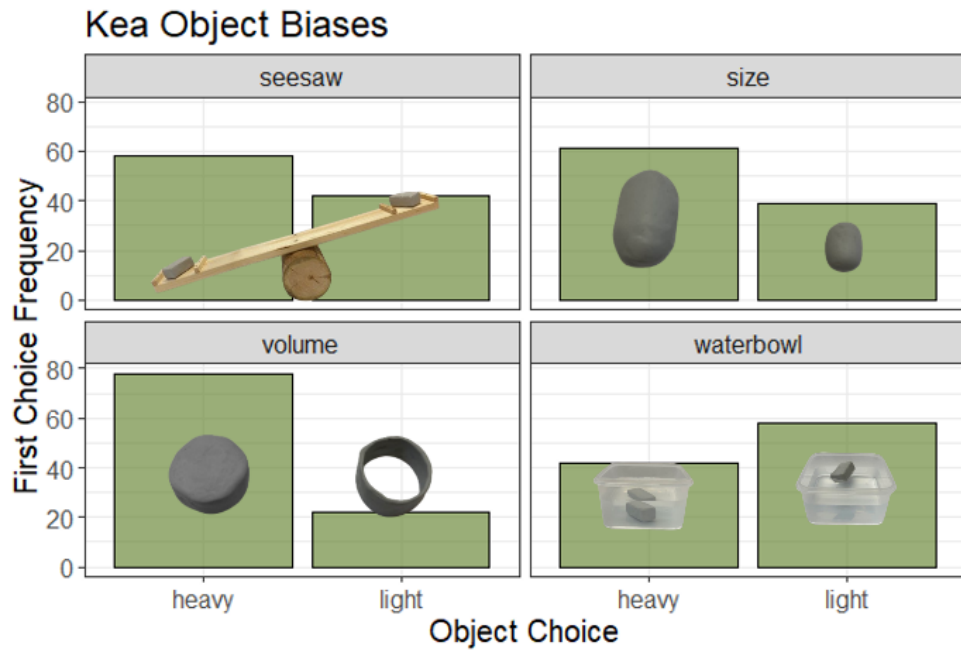


Figure 9: Frequency of object choice in Kea irrespective of target weight over all trials.

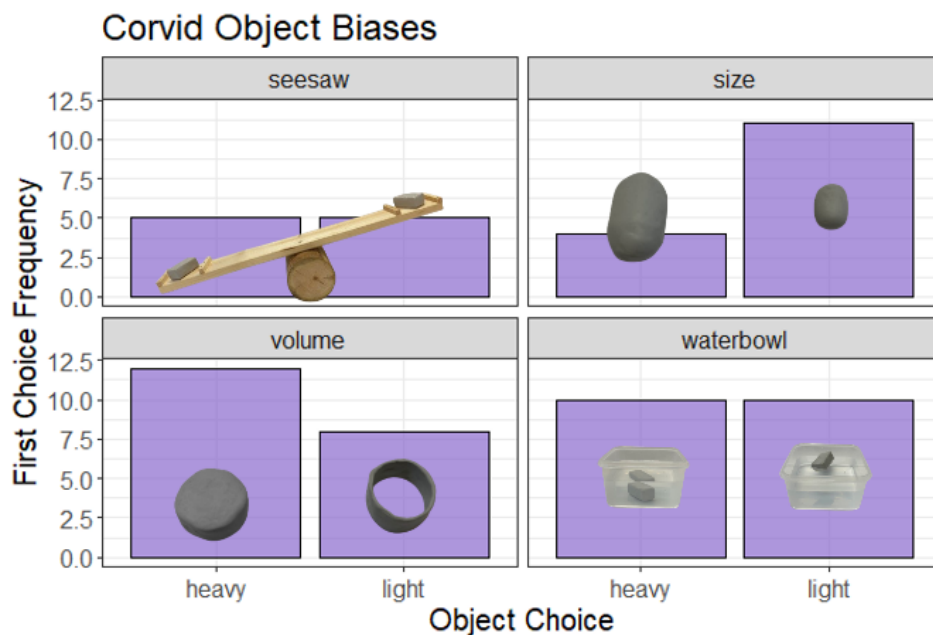


Figure 10: Frequency of object choice in corvids, all light target weight over all trials.

Kea did not have a noticeable side bias in any of the conditions (Figure 11), whereas corvids approached the right side more frequently in both the waterbowl and the size condition (Figure 11). Corvids did not have any side preference in the volume condition, but had a side preference toward the left in the seesaw condition (Figure 11).

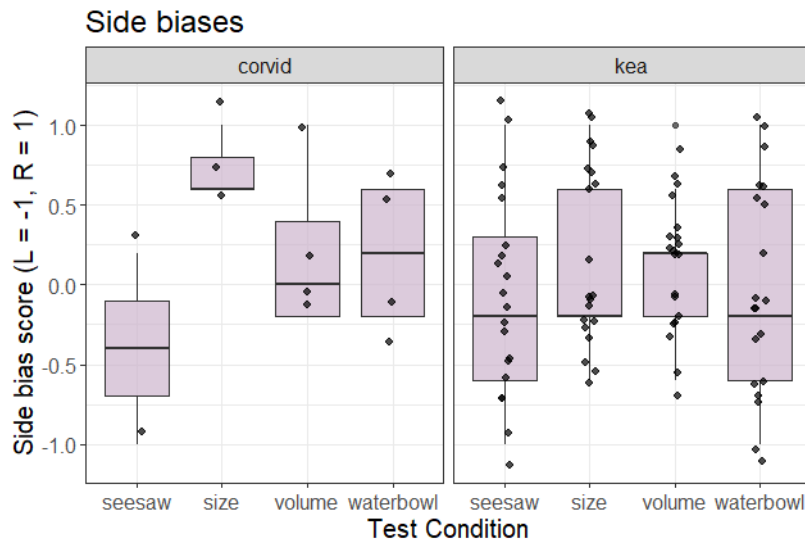


Figure 11: Comparison of Side biases between corvids and kea during test conditions

## Exploration behaviors during Habituation Sessions

In both the water and the seesaw habituation sessions, corvids showed a higher latency to contact the testing materials in comparison to the Kea (Figure 11).

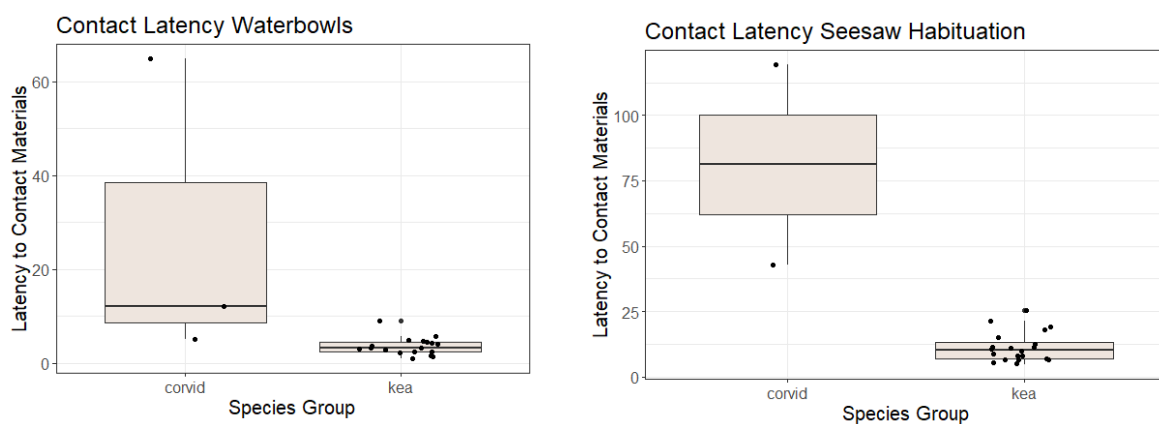


Figure 12: Species Comparison of latency to contact materials (in s) during habituation sessions. L: Contact latency during the waterbowl habituation session, R: Contact latency during seesaw habituation session.

Additionally, Kea spent more time on average manipulating test materials in comparison to the corvids in both water and seesaw habituation sessions (Figure 13).



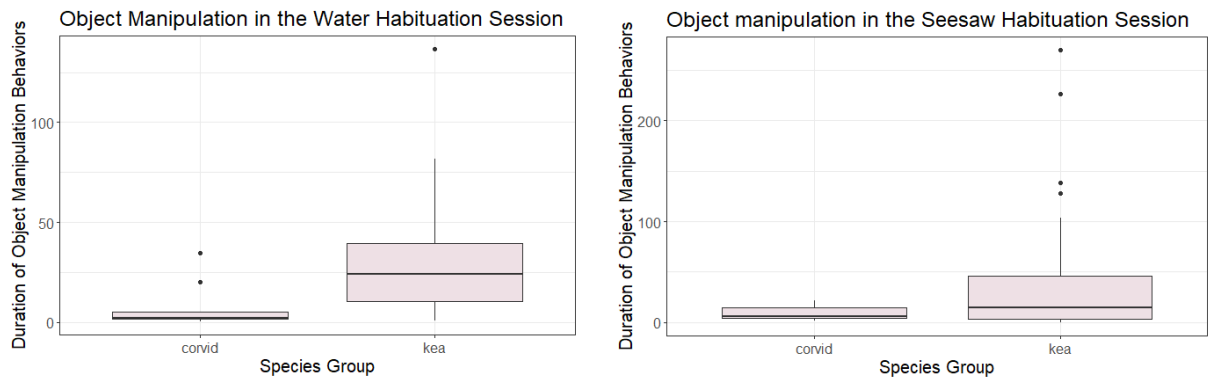


Figure 13: Species comparison of duration of object manipulation during habituation sessions (in s). L: Waterbowl habituation session, R: Seesaw habituation session.

When looking at the relative frequency of specific object manipulation behaviors during the seesaw habituation session, keas showed a higher diversity in comparison to the corvids (Figure 14) during the seesaw session. However, both species mostly used their beak to remove the cups (Figure 14).

In the water habituation session, Kea again showed a bigger diversity of object manipulation behaviors in comparison to the corvids (Figure 14). But the relative role of exploration behaviors (Figure 14) seemed to be similar between the species groups.

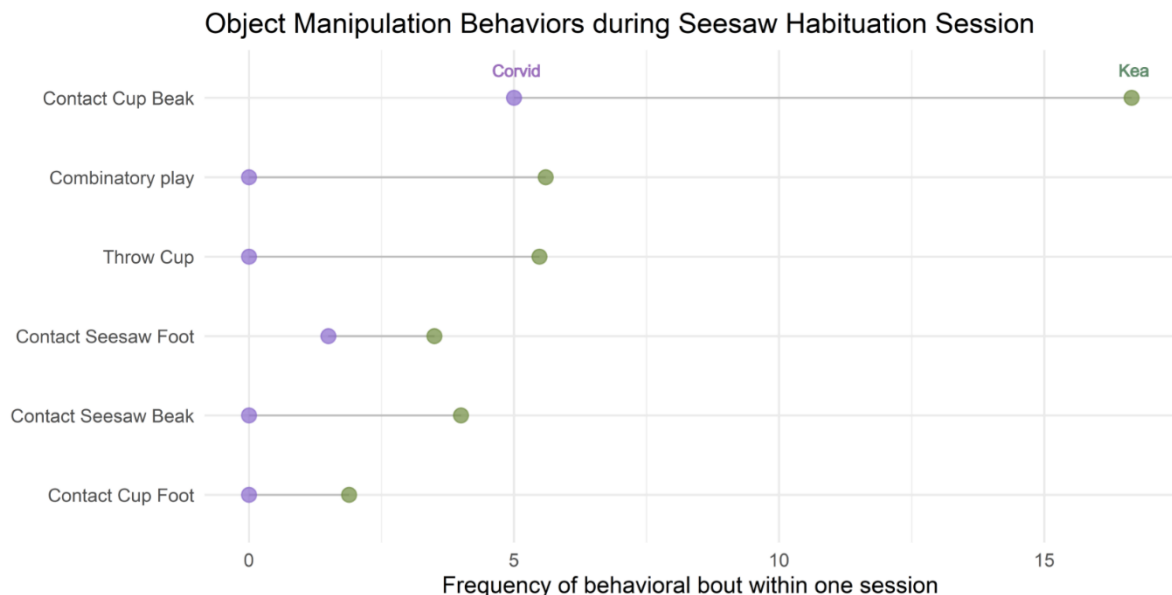


Figure 14: Variety of object manipulation behaviors during seesaw habituation session in kea (green) vs corvids (purple). The x-axis indicates the mean frequency each behavior was shown during the habituation sessions for each species. Detailed Descriptions of each behavior can be found in the Appendix A2..

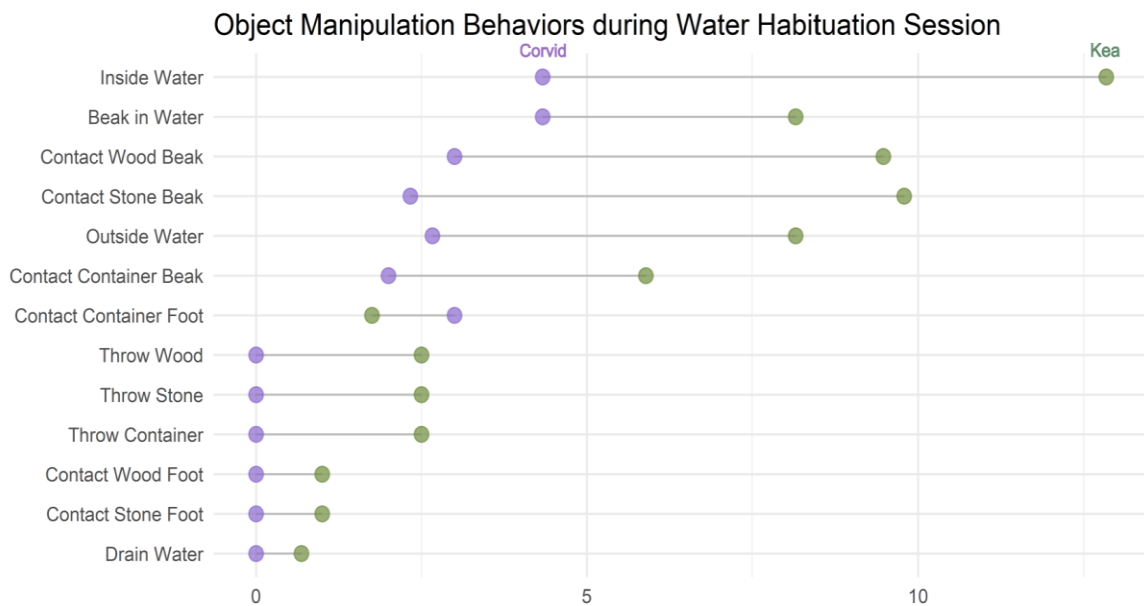


Figure 14: Variety of object manipulation behaviors during water habituation session in kea (green) vs corvids (purple). The x-axis indicates the mean frequency each behavior was shown during the habituation sessions for each species. Detailed Descriptions of each behavior can be found in the Appendix.

## Exploratory Analyses

To see whether exploration in the habituation sessions improved the Kea's use of visual information during testing, two GLMMS for each the waterbowl and the seesaw conditions were run. In both models, no predictor had a significant effect on the Kea's first choice, and both models were not better at predicting first choice than a null model (Waterbowl:  $\chi^2 = 3.92$ ,  $df = 3$ ,  $p = .27$  (Table 9), Seesaw:  $\chi^2 = 3.737$ ,  $df = 4$ ,  $p = .44$ , (Table 10)). Thus, exploration did not influence the Kea's use of visual information.

Table 9: Results from model 8. Influence of object exploration during waterbowl habituation session on weight inference during testing.

First Choice in Waterbowl T1 ~ Object Manipulation dur Waterbowl + Days to Test + Target Weight				
Term	Estimate	Std. Error	z-value	p-value
Intercept	0.2104	1.0920	0.19	0.85
Object Manipulation	0.0238	0.0217	1.10	0.27
Days to Test	-0.3364	0.2383	-1.41	0.16
Target Weight	-0.7435	1.1369	-0.65	0.51

Table 10: Results from model 9: Influence of object exploration during seesaw habituation session on weight inference during testing.

<b>First Choice in Seesaw T1 ~ beam movement + combinatory object play + Days to Test + Target Weight</b>				
Term	Estimate	Std. Error	z-value	p-value
Intercept	1.307	2.826	0.46	0.64
Beam Movement	-0.110	0.227	-0.49	0.63
Combinatory Play	0.129	0.128	1.01	0.31
Target Weight	-1.036	1.009	-1.03	0.30
Days to test	0.254	0.271	0.94	0.35

## DISCUSSION

To summarize, context (as measured by test condition) did affect the subjects' use of visual information during testing (H1). However, most subjects showed object biases toward certain test objects especially in the volume condition. Over all trials, neither kea nor corvids used visual information to infer object weight (H2) and did not use this information as the task progressed. But, corvids may use visual information more than the kea in the first trial while objects are still novel. Notably, this is not a significant effect and would need to be replicated with more data from the corvids. Generally, both kea and corvids more heavily relied on tactile information to discriminate the test objects (H3).

### Training – learning to use a tactile cue

During training, corvids seem to take longer overall than the kea when learning to use the tactile cue of an object's weight. Nonetheless, two corvids did learn on par with the kea. Individuals in the heavy group had the most difficulties in doing so, with some subjects never passing the training and others stopping to participate overall. The reason for this could be three-fold:

Firstly, the corvids may have avoided exerting physical energy when lifting the heavier object. In a study comparing Kea and Common ravens in inferential reasoning (Schloegl, 2009), ravens seemed to minimize their effort to solve the task, whereas the Kea kept exploring and interacting with the setup. Similarly, kea show higher perseverance when exploring objects in comparison to New Caledonian crows (Auersperg, 2011). Because of their tactile bias, kea may demonstrate more tolerance towards manipulating and lifting the heavier object in comparison to the corvids and thus had better training success.

Secondly, especially in the crows where most drop outs occurred, the light target weight is close to the weight of a walnut. In the wild, crows will drop walnuts to break them open (Cristol & Switzer, 1999) and attend to object properties such as size to select which nuts to eat (Cristol, 2001). This may have biased the crows toward the light object after manipulation. Crows even showed similar dropping behaviors toward the training objects, indicating they may have perceived some parallels between walnuts and the artificial objects used in this study. Notably, this most likely did not influence the crows' performance during the size condition of testing, as the light object was significantly smaller than a walnut.

Thirdly, it is possible that accidentally the light target weight was assigned to the bolder individuals, but this is highly unlikely as target weights were assigned before any of the birds were trained.

Although the corvids took more sessions on average to be trained than the kea, they were faster than chimpanzees (Povinelli, 2012). Their performance was comparable to Goffins cockatoos (Lambert et al., 2021), further underlining that birds may have an advantage when discriminating objects based on their weight alone. Weight related signals may have a high relevance for airborne species when transporting materials (Lambert et al., 2021; Povinelli, 2012). This could be exemplified by nestbuilding, which involves picking up and transporting materials of different weights and is energetically costly (Mainwaring & Hartley, 2013).

### Visual information use depending on context

In the kea, visual information was dependent on test condition over all trials but not in the first trial. Interestingly, whether the cues to object weight were inherent to the object itself (e.g. in the volume and the size condition) or within the objects' interaction with other structures (in the seesaw and the water condition) did not seem to make a difference. There was also no pattern in visual information use that would point towards an influence of ecological factors, since birds performed worse in the water condition than in the seesaw but better in the size condition than in the volume. Most likely, the differences in conditions that are seen in the kea are due to object biases which are discussed below (see object biases).

When looking at the corvids, they seemed to attend to visual information in the size condition but not in other conditions. Size may be a very basal object property that birds can attend to from birth (Vallortigara, 2012), and thus may lend itself to infer other object

properties more easily as opposed to more abstract and less ecologically relevant conditions present in this study (e.g. seesaw, volume).

Both kea and corvids did not use visual information during the water condition. This was somewhat unexpected, as the ravens and crows were often observed dropping stones and other objects, including the training objects, into their water pools. Moreover, the kea are fed grain in their water pools daily (where some seeds will sink and other will float), after which they manipulate the water using their feet to reach all seeds. Consequently, both the kea and the corvids that participated here are familiar with floating lighter objects and sinking heavy objects. However, no corvid to date has demonstrated an understanding of water displacement without training (reviewed in Jelbert et al., 2015), and the performance of New Caledonian crows that passed aesop's task could be explainable by trial-and-error learning (Hennefield et al., 2018) or object biases (Miller et al., 2016). Also the kea tested on the aesop task also did not demonstrate an understanding of water displacement (Schwing et al., 2016). This may suggest that nonhuman animals may either not have an understanding of the physical properties of water without extensive experience, or they may not be able to transfer their knowledge of these properties to more abstract physical cognition tasks (i.e. tasks with man-made objects).

In the seesaw condition, kea had a slight bias toward the heavier object whereas the corvids did not. Seesaw mechanisms have previously been used for studies on cooperation and sociality in both corvids (Horn et al., 2016) and kea (Federspiel et al., 2005). In both studies, birds were able to use the seesaw mechanism to either provide food for conspecifics (corvids) or cooperate with others to reach a reward (kea) which indicates that they can learn to use this type of mechanism. However, it may make a difference if the effect of the mechanism is experienced through one's own weight (as in both studies mentioned above) or through observation of an object. Chimpanzees seemingly are able to make this inference when locating food (Hanus & Call., 2008) but their performance would also be explainable by going for the side of the seesaw that goes down which may be more salient (Povinelli 2012). The latter would match the kea's performance in this study. Furthermore, chimpanzees have difficulties selecting a heavy object to dislocate an apple placed on a seesaw (Povinelli, 2012), which may further indicate a limited understanding of how objects interact with human-made mechanisms in nonhuman animals.

## Object biases

The kea especially showed signs of visual object biases during the test sessions. These biases would also correspond to the significant interaction effects present in the model. In 3 out of 4 conditions, kea in both the light and heavy groups had a slight (seesaw and size) or very strong (volume) preference for choosing the heavier object. This may explain why Kea in the light group were overall worse in using visual information, but better in the waterbowl condition, where the light object was more accessible.

The object preferences in the corvids need to be interpreted differently, since they are not present irrespective of target weight but only in the light group (because there is no data from birds in the heavy group). There were no preferences in the waterbowl and seesaw conditions, suggesting that corvids did not at all attend to the visual information here. Similar to the kea, the corvids also preferred the heavy object in the volume condition. The heavy volume object (Figure 2) was more similar to the other test objects, whereas the hole and ring shape of the light volume object may represent an extremely unnatural object shape. This unfamiliarity of the light in combination with familiarity of the heavy volume object may explain the birds' preference for the heavy object. As already mentioned in the case of the crows, similarities between the test objects and walnuts may have also played a role in this bias.

## Visual information use between species groups

Neither kea nor corvids seemed to consistently attend to visual cues as a cue to object weight in this study and also did not attend to them as the task progressed. Specifically, they did not choose their target object based on visual information after learning which one is correct after trial 1. This is in opposition to Lambert et al., 2017, where some subjects were able to use object color as a cue for object weight as the task progressed. This difference may lie in the specific expression of the within-object cue, as all objects in this study were grey in color and the cue to weight was within the shape of the object. Although object recognition mechanisms are shared between primates and birds so it is likely object shapes are perceived in a similar fashion as in humans (Soto & Wasserman, 2012), color may be a more salient cue compared other object properties such shape (Lazareva et al., 2005).

Corvids showed a trend to use visual information more than the kea when the objects were still novel. It is possible that the kea in the light group performed worse due to object biases,

rather than the corvids truly using visual information. Nevertheless, the corvid sample is too small to make a resilient species comparison in visual information use. In contrast to New Caledonian crows (Jelbert et al., 2019) crows and ravens in this study did not consistently touch the correct object first. This may again be due to object color providing additional useful information for object discrimination (Lambert et al., 2017) or due to a limited understanding for the properties of water and seesaws, or biases against unnatural object shapes (as already discussed previously). Notably, New Caledonian crows are tool users (Hunt, 1996) in comparison to carrion crows, so it is possible they have an especially sophisticated understanding of object weight both with and without handling, even though their cognitive abilities were comparable in a study investigating their physical cognition (Teschke et al., 2013). Understanding one's own movement as well as the movements of objects in a breeze may be a matter of survival when flying through strong winds or a storm. Therefore, weight inference may be a more adaptive skill in the context of "wind pressure" in comparison to object size, shape, water forces or the effect of weight on a seesaw.

### Tactile Information use during test sessions

During testing, both kea and corvids were highly accurate when using the tactile cues to solve the tasks as opposed to the visual cues. This indicates that subjects did understand the task, as they were trained to solely rely on tactile cues before testing and were then able to use this skill in the novel test conditions. Most importantly, it was always possible for the birds to touch both objects, so there was no strong incentive to use visual information to return their target object. Thus, both species groups may have relied on the most reliable way to gain information about object weight – touching (Povinelli 2012) and did not infer object weight based on visual information.

In doing this, subjects attended to affordances in the context of testing. The lack of a forced choice may have shifted the subjects' strategy so that the available visual information was no longer relevant to solve the task. Here, the kea may have been at an advantage, as not only did they have previous experience with weight studies, but also their higher readiness to manipulate objects may help them to detect functional affordances (Auersperg et al., 2011). Nevertheless, imposing a cost in other weight studies has not seemed to improve the kea's performance in weight inference, indicating their ability to use visual information may indeed be limited.

## Exploration and Neotic style differences

In the habituation sessions, the originally assumed exploration and neotic style differences between the Kea and both Corvid species did arise. Corvids had higher latencies to approach the test objects and thus displayed rates of initial neophobia. While exploring, corvids had a lower variety of tactile behaviors in comparison to the Kea. This is in accordance with differences in exploratory behaviors found comparing New Caledonian crows and kea (Lambert et al., 2017). As opposed to O'Hara et al., 2017, the corvids did not explore later, but less overall and also showed less interest in continuous exploration of testing materials than the kea. However, it is also possible that the corvids would have started exploring after multiple habituation sessions, which they did not get. Furthermore, all corvids tested were over 10 years old. Younger individuals may have explored more as neophilia declines with age in corvids (Heinrich, 1995). Previous experience with the setup did not improve the kea test success, further indicating that to use visual information was simply not relevant for them to solve this specific task.

## Conclusion & Outlook

To summarize, neither the corvids nor the kea convincingly used visual information to choose their target object. Instead, both groups relied on using tactile information overall, which in this case was in accordance with affordances of the task. No claim on weight inference can be made here for any of the species tested. This is in accordance with studies on weight inference in chimpanzees (Povinelli, 2012) and previous studies on kea (Temeroli et al., 2024). The lack in species differences in visual information use found here mirrors previous results from kea and new caledonian crows (Lambert et al., 2017). Also, differences in exploration behaviors match comparisons of kea and new caledonian crows (Lambert et al., 2017) as well as comparisons of kea and ravens (Schloegl et al., 2009). Still, there was a trend towards significance when comparing the kea to the corvids in the first trial. This may indicate that the corvids did attend more to visual information than kea in the light group while objects were still novel. Nonetheless, the results presented here are limited by the small sample size of the corvids. Additional data from corvids in the heavy group would be needed to get a more complete picture. This may hint at neotic responses acting as a modulator for how environmental information is used to interact with object properties. However, the corvids weight inference performance did not parallel new caledonian crows as originally expected (Jelbert et al., 2019). Taken together, whether visual information is used



to infer object weight may mostly depend on a species' necessity to do so in a given task and may be highly context-specific. Future studies in a similar direction should more strongly focus on ecological relevance of weight inference, as well as incorporate more variation in object color and test a higher number of novel objects with varying properties. Moreover, it may be interesting to more directly investigate interactions between neotic responses and the perception of salient object properties, e.g. by measuring neotic responses to the specific tasks during testing and investigating their effects on task performance.

## REFERENCES

- Auersperg, A. M., Von Bayern, A. M., Gajdon, G. K., Huber, L., & Kacelnik, A. (2011). Flexibility in problem solving and tool use of kea and New Caledonian crows in a multi access box paradigm. *PloS one*, 6(6), e20231.
- Baayen, R. H. (2008). *Analyzing Linguistic Data*. Cambridge University Press, Cambridge.
- Barnett, S. A. (1958). Experiments on 'neophobia' in wild and laboratory rats. *British journal of psychology*, 49(3), 195-201.
- Bates D., Maechler, M., Bolker, B., Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67(1), 1-48. doi:10.18637/jss.v067.i01.
- Chemero, A. (2018). An outline of a theory of affordances. In *How shall affordances be refined?* (pp. 181-195). Routledge.
- Corey, D. T. (1978). The determinants of exploration and neophobia. *Neuroscience & Biobehavioral Reviews*, 2(4), 235-253.
- Cristol, D. A. (2001). American crows cache less preferred walnuts. *Animal Behaviour*, 62(2), 331-336.
- Cristol, D. A., & Switzer, P. V. (1999). Avian prey-dropping behavior. II. American crows and walnuts. *Behavioral Ecology*, 10(3), 220-226.
- Dall, S. R., Giraldeau, L. A., Olsson, O., McNamara, J. M., & Stephens, D. W. (2005). Information and its use by animals in evolutionary ecology. *Trends in ecology & evolution*, 20(4), 187-193.
- Dobson, A. J. (2002). *An Introduction to Generalized Linear Models*. Chapman Hall/CRC, Boca Raton.
- Emery, N. J. (2006). Cognitive ornithology: the evolution of avian intelligence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 361(1465), 23-43.
- Federspiel, I., Gajdon, G., & Huber, L. (2005). Do keas, *Nestor notabilis*, switch from unprofitable cooperative behaviour to alternative solutions?. In *XXIX International Ethological Conference (IEC)*.
- Friard, O., & Gamba, M. (2016). BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations. *Methods in Ecology and Evolution*, 7(11), 1325–1330.
- Forstmeier, W. and Schielzeth, H. (2011). Cryptic multiple hypotheses testing in linear models: overestimated
- Greenberg, R. S. (2003). The role of neophobia and neophilia in the development of innovative behaviour of birds. *Animal innovation*.

- Greenberg, R., & Mettke-Hofmann, C. (2001). Ecological aspects of neophobia and neophilia in birds. *Current ornithology*, 119-178.
- Griffin, A. S., & Guez, D. (2014). Innovation and problem solving: a review of common mechanisms. *Behavioural Processes*, 109, 121-134.
- Hanus, D., & Call, J. (2008). Chimpanzees infer the location of a reward on the basis of the effect of its weight. *Current Biology*, 18(9), R370-R372.
- Heinrich, B. (1995). Neophilia and exploration in juvenile common ravens, *Corvus corax*. *Animal Behaviour*, 50(3), 695-704
- Heinrich, B. (2014). Ravens in winter. Simon and Schuster.
- Heinrich, B. (1988). Why do ravens fear their food?. *Condor*, 950-952.
- Heinrich, B., Joerg, C. C., Madden, S. S., & Sanders Jr, E. W. (1997). Black-capped Chickadees and Red-breasted Nuthatches Weigh" Sunflower Seeds". *The Auk*, 114(2), 17.
- Heinrich, B., Marzluff, J., & Adams, W. (1995). Fear and food recognition in naive common ravens. *The Auk*, 112(2), 499-503.
- Henley, T. (2020). Do New Caledonian crows represent< weight>? An Analysis of Jelbert et al.(2019). *Animal Behavior and Cognition*, 7(4), 661-664.
- Hennefield, L., Hwang, H. G., Weston, S. J., & Povinelli, D. J. (2018). Meta-analytic techniques reveal that corvid causal reasoning in the Aesop's Fable paradigm is driven by trial-and-error learning. *Animal cognition*, 21, 735-748.
- Horn, L., Scheer, C., Bugnyar, T., & Massen, J. J. (2016). Proactive prosociality in a cooperatively breeding corvid, the azure-winged magpie (*Cyanopica cyana*). *Biology letters*, 12(10), 20160649.
- Huber, L., & Gajdon, G. K. (2006). Technical intelligence in animals: the kea model. *Animal cognition*, 9, 295-305.
- Hunt, G. R. (1996). Manufacture and use of hook-tools by New Caledonian crows. *Nature*, 379(6562), 249-251.
- Jablonski, P. G., Lee, S. I., Fuszara, E., Fuszara, M., Jeong, C., & Lee, W. Y. (2015). Proximate mechanisms of detecting nut properties in a wild population of Mexican Jays (*Aphelocoma ultramarina*). *Journal of Ornithology*, 156(1), 163-172.

- Jelbert, S. A., Miller, R., Schiestl, M., Boeckle, M., Cheke, L. G., Gray, R. D., ... & Clayton, N. S. (2019). New Caledonian crows infer the weight of objects from observing their movements in a breeze. *Proceedings of the Royal Society B*, 286(1894), 20182332.
- Jelbert, S. A., Taylor, A. H., & Gray, R. D. (2015). Investigating animal cognition with the Aesop's Fable paradigm: Current understanding and future directions. *Communicative & integrative biology*, 8(4), e1035846.
- Kaiser, M. K., & Proffitt, D. R. (1984). The development of sensitivity to causally relevant dynamic information. *Child Development*, 1614-1624.
- Krauzlis, R. J., Bogadhi, A. R., Herman, J. P., & Bollimunta, A. (2018). Selective attention without a neocortex. *Cortex*, 102, 161-175.
- Lazareva, O. F., Vecera, S. P., Levin, J., & Wasserman, E. A. (2005). Object discrimination by pigeons: Effects of object color and shape. *Behavioural Processes*, 69(1), 17-31.
- Lambert, M. L., Jacobs, I., Osvath, M., & von Bayern, A. M. (2019). Birds of a feather? Parrot and corvid cognition compared. *Behaviour*, 156(5-8), 505-594.
- Lambert, M. L., Schiestl, M., Schwing, R., Taylor, A. H., Gajdon, G. K., Slocombe, K. E., & Seed, A. M. (2017). Function and flexibility of object exploration in kea and New Caledonian crows. *Royal Society Open Science*, 4(9), 170652.
- Lambert, P. J., Stiegler, A., Rössler, T., Lambert, M. L., & Auersperg, A. M. (2021). Goffin's cockatoos discriminate objects based on weight alone. *Biology Letters*, 17(9), 20210250.
- Langen, T. A. (1999). How western scrub-jays (*Aphelocoma californica*) select a nut: effects of the number of options, variation in nut size, and social competition among foragers. *Animal Cognition*, 2, 223-233.
- Lüdecke et al., (2021). see: An R Package for Visualizing Statistical Models. *Journal of Open Source Software*, 6(64), 3393. <https://doi.org/10.21105/joss.03393>
- Mainwaring, M. C., & Hartley, I. R. (2013). The energetic costs of nest building in birds. *Avian biology research*, 6(1), 12-17.
- Manrique, H. M., Gross, A. N. M., & Call, J. (2010). Great apes select tools on the basis of their rigidity. *Journal of Experimental Psychology: Animal Behavior Processes*, 36(4), 409.
- McCulloch, T. L. (1941). Discrimination of lifted weights by chimpanzees. *Journal of Comparative Psychology*, 32(3), 507.

- Miller, R., Jelbert, S. A., Taylor, A. H., Cheke, L. G., Gray, R. D., Loissel, E., & Clayton, N. S. (2016). Performance in object-choice Aesop's Fable tasks are influenced by object biases in New Caledonian crows but not in human children. *Plos One*, 11(12), e0168056.
- Miller, R., Lambert, M. L., Frohnwieser, A., Brecht, K. F., Bugnyar, T., Crampton, I., ... & Clayton, N. S. (2022). Socio-ecological correlates of neophobia in corvids. *Current Biology*, 32(1), 74-85.
- Mikolasch, S., Kotrschal, K., & Schloegl, C. (2012). Is caching the key to exclusion in corvids? The case of carrion crows (*Corvus corone corone*). *Animal Cognition*, 15(1), 73-82.
- O'Hara, M., Mioduszevska, B., Von Bayern, A., Auersperg, A., Bugnyar, T., Wilkinson, A., ... & Gajdon, G. K. (2017). The temporal dependence of exploration on neotictic style in birds. *Scientific Reports*, 7(1), 4742.
- O'Hara, M., Schwing, R., Federspiel, I., Gajdon, G. K., & Huber, L. (2016). Reasoning by exclusion in the kea (*Nestor notabilis*). *Animal Cognition*, 19, 965-975.
- Osvath, M., Kabadayi, C., & Jacobs, I. (2014). Independent evolution of similar complex cognitive skills.
- Pika, S., Sima, M. J., Blum, C. R., Herrmann, E., & Mundry, R. (2020). Ravens parallel great apes in physical and social cognitive skills. *Scientific Reports*, 10(1), 20617.
- Povinelli, D. (2012). *World without weight: Perspectives on an alien mind*. Oxford University Press, USA. effect sizes and the winners curse. *Behavioural Ecology and Sociobiology*, 65:47–55.
- R Core Team (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.
- Schloegl, C., Dierks, A., Gajdon, G. K., Huber, L., Kotrschal, K., & Bugnyar, T. (2009). What you see is what you get? Exclusion performances in ravens and keas. *Plos one*, 4(8), e6368.
- Schrauf, C., & Call, J. (2009). Great apes' performance in discriminating weight and achromatic color. *Animal Cognition*, 12, 567-574.
- Schrauf, C., Huber, L., & Visalberghi, E. (2008). Do capuchin monkeys use weight to select hammer tools?. *Animal Cognition*, 11, 413-422.
- Schwing, R., Weiss, F., Tichy, A., & Gajdon, G. (2019). Testing the causal understanding of water displacement by kea (*Nestor notabilis*). *Behaviour*, 156(5-8), 447-478.

Soto, F. A., & Wasserman, E. A. (2012). Visual object categorization in birds and primates: Integrating behavioral, neurobiological, and computational evidence within a “general process” framework. *Cognitive, Affective, & Behavioral Neuroscience*, 12, 220-240.

Spelke, E. S. (2000). Core knowledge. *American psychologist*, 55(11), 1233.

Spelke, E. S. (2010). Core systems and the growth of human knowledge: Natural geometry. *Human Neuroplasticity and Education*, 27, 73-99.

Spelke, E. S., & Kinzler, K. D. (2007). Core knowledge. *Developmental science*, 10(1), 89-96.

Temeroli, E., Jelbert, S. A., & Lambert, M. L. (2024). Do kea parrots infer the weight of objects from their movement in a breeze?. *Biology Letters*, 20(11), 20240405.

Teschke, I., Wascher, C. A., Scriba, M. F., von Bayern, A. M., Huml, V., Siemers, B., & Tebbich, S. (2013). Did tool-use evolve with enhanced physical cognitive abilities?. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 368(1630), 20120418.

Turvey, M. T. (2019). *Lectures on perception: An ecological perspective*. New York: Routledge.

Vallortigara, G. (2012). Core knowledge of object, number, and geometry: A comparative and neural approach. *Cognitive neuropsychology*, 29(1-2), 213-236.

Visalberghi, E., Addessi, E., Truppa, V., Spagnoletti, N., Ottoni, E., Izar, P., & Frigaszy, D. (2009). Selection of effective stone tools by wild bearded capuchin monkeys. *Current Biology*, 19(3), 213-217.

Visalberghi, E., & Néel, C. (2003). Tufted capuchins (*Cebus apella*) use weight and sound to choose between full and empty nuts. *Ecological Psychology*, 15(3), 215-228.

Wagman, J. B., Lozano, S., Jiménez, A., Covarrubias, P., & Cabrera, F. (2019). Perception of affordances in the animal kingdom and beyond. *Aproximaciones al estudio del comportamiento y sus aplicaciones*, 2, 70-108.

Wickham., H. (2016) *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York

Wickham et al., (2019). Welcome to the tidyverse. *Journal of Open Source Software*, 4(43), 1686, <https://doi.org/10.21105/joss.01686>

Yorzinski, J. L., Patricelli, G. L., Babcock, J. S., Pearson, J. M., & Platt, M. L. (2013). Through their eyes: selective attention in peahens during courtship. *Journal of Experimental Biology*, 216(16), 3035-3046.

Yorzinski, J. L., & Platt, M. L. (2014). Selective attention in peacocks during predator detection. *Animal Cognition*, 17, 767-777.

*This page is intentionally left blank*

## Appendix

### *A1. Ethogram Waterbowl session*

Behavior Name	Definition	Modifier set 1	Modifier set 2
Object contact	Bird is in contact with object	Stone   Wood   Container	Beak   Foot
Beak in Water	Bird is only contacting the water using the beak, no objects	none	None
Throw object	Bird is throwing the object (with a hauling motion)	Stone   Wood   Container	None
Drain	Bird is tipping over the container and thus draining the water	none	None
Latency to contact Materials	Time from door open enough for the bird to fit through to first contacted material	Stone   Wood   Container	Beak   Foot
Manipulate Inside Water	Bird is manipulating wood or stone inside water	None	None
Manipulate Outside Water	Bird is manipulating wood or stone outside water	None	None
Experimenter Encouragement	Bird is experiencing encouragement by the Experimenter	None	None



*A2: Ethogram Seesaw Session*

Behavior Name	Definition	Modifier set 1	Modifier set 2
Object contact	Bird is in contact with object	Cup A   Cup B   Seesaw	Beak   Foot
Throw object	Bird is throwing the object (with a hauling motion)	Cup A   Cup B   Seesaw	None
First Choice	Side of cup the bird is choosing to lift	Cup L   Cup R	None
Beam movement	Time from start of beam movement to end of beam movement	None	None
Latency to contact Materials	Time from door open enough for the bird to fit through to first contacted material	Cup A   Cup B   Seesaw	Beak   Foot
Combinatory Object Play	Any behavior that is making objects touch one another – e.g. bird is putting cups on top of beam	None	None

```
##### KEA & CORVID WEIGHT PERCEPTION #####

# Masterthesis Anna Elisa Kempf, Feb. 2025

options("scipen"=100, "digits"=4)


#Load all needed packages

library(tidyverse)

library(lme4)

library(readxl)

library(Rmisc)

library(ggplot2)

library(performance)

library(partR2)

library("see")


#function to check models for overdispersion (from
https://bbolker.github.io/mixedmodels-misc/glmmFAQ.html#testing-for-overdispersioncomputing-overdispersion-factor)

overdisp_fun <- function(model) {

  rdf <- df.residual(model)

  rp <- residuals(model,type="pearson")

  Pearson.chisq <- sum(rp^2)

  prat <- Pearson.chisq/rdf

  pval <- pchisq(Pearson.chisq, df=rdf, lower.tail=FALSE)

  c(chisq=Pearson.chisq,ratio=prat,rdf=rdf,p=pval)

}
```

```
### Main Analysis ###
```

```
#TESTING_Data <-  
read_excel("~/UNI//MASTER//MASTERARBEIT//TESTING_Data.xlsx",  
            #sheet = "Testing_Data")  
  
df_kea <- TESTING_Data %>% filter(Species == "kea") #kea only
```

```
#Create A Dataset of just the first Trial  
  
df_kea_T1 <- df_kea %>% filter(Trial_Nr == 1)  
df_all_T1 <- TESTING_Data %>% filter(Trial_Nr == 1)
```

```
### HYPOTHESIS 1: CONTEXT ###
```

```
## MODEL 1: First Choice First Trial between conditions
```

```
#Null model - Only individual differences
```

```
M1.0 <- glmer((First_Choice ~ 1 + (1|ID)), data = df_kea_T1, family =  
binomial)  
  
summary(M1.0)
```

```
#Full Model - does target weight or test condition have an effect on  
first choice
```

```
M1.1 <- glmer((First_Choice ~ Test_Condition * Target_Weight + Sex +  
(1|ID)), data = df_kea_T1, family = binomial)  
  
summary(M1.1)
```

```

check_model(M1.1, check = "outliers", )
check_model(M1.1, check = "binned_residuals")
overdisp_fun(M1.1)

#Remove Interaction of Condition and Target Weight
M1.2 <- glmer((First_Choice ~ Test_Condition + Target_Weight + Sex +
(1|ID)), data = df_kea_T1, family = binomial)
summary(M1.2)
check_model(M1.2, check = "outliers", )
check_model(M1.2, check = "binned_residuals")
overdisp_fun(M1.2)

#Full-Null-Comparison
as.data.frame(anova(M1.0, M1.2, test="Chisq"))

## MODEL 2: How did the Kea do in the different Conditions for all
trials?

#Null Model
M2.0 <- glmer(First_Choice ~ 1 + (1|ID), data = df_kea, family =
binomial)
summary(M2.0)
check_model(M2.0, check = "outliers", )
check_model(M2.0, check = "binned_residuals")
overdisp_fun(M2.0)

#Full Model with interactions

```

```

M2.1 <- glmer(First_Choice ~ Test_Condition * Target_Weight + Sex +
as.factor(Trial_Nr) + (1|ID), data = df_kea, family = binomial)

summary(M2.1)

check_model(M2.1, check = "outliers", )

check_model(M2.1, check = "binned_residuals")

overdisp_fun(M2.1)


#Full-Null-Comparison

as.data.frame(anova(M2.0, M2.1, test="Chisq"))


### HYPOTHESIS 2: COMPARATIVE ANALYSIS ###


## MODEL 3: Species Comparison in first Trial

#Null model

M3.0 <- glmer(First_Choice ~ 1 + (1|ID), data = df_all_T1, family =
binomial(link="logit"))

check_model(M3.0, check = "outliers", )

check_model(M3.0, check = "binned_residuals")

overdisp_fun(M3.0)


#Full model

M3.1 <- glmer(First_Choice ~ Species_Group + Test_Condition + Sex +
Target_Weight + (1|ID), data = df_all_T1, family =
binomial(link="logit"))

summary(M3.1)

check_model(M3.1, check = "outliers", )

```

```

check_model(M3.1, check = "binned_residuals")

overdisp_fun(M3.1)


#Full-Null-Comparison
as.data.frame(anova(3.0, M3.1, test="Chisq"))


## MODEL 4: Species Comparison in all trials


#Null Model

M4.0 <- glmer(First_Choice ~ 1 + (1|ID), data = TESTING_Data, family =
binomial)

summary(M4.0)

check_model(M4.0, check = "outliers")

check_model(M4.0, check = "binned_residuals")

overdisp_fun(M4.0)


#Full model

M4.1 <- glmer(First_Choice ~ Species_Group + Test_Condition + Sex +
Trial_Nr + Target_Weight + (1|ID), data = TESTING_Data, family =
binomial(link="logit"))

summary(M4.1)

check_model(M4.1, check = "outliers", )

check_model(M4.1, check = "binned_residuals")

overdisp_fun(M4.1)


#Full-Null-Comparison
as.data.frame(anova(M4.0, M4.1, test="Chisq"))

```

```
### HYPOTHESIS 3 ###
```

```
## MODEL 5+6: Are Kea and Corvids better than chance in Final Choice?
```

```
#Kea
```

```
M5 <- glmer(Final_Choice ~ 1+(1|ID), data = df_kea, family = binomial)
```

```
summary(M5)
```

```
check_model(M5, check = "outliers")
```

```
check_model(M5, check = "binned_residuals")
```

```
overdisp_fun(M5)
```

```
#Corvids
```

```
M6 <- glmer(Final_Choice ~ 1+(1|ID), data = df_corvids, family =  
binomial)
```

```
summary(M6)
```

```
check_model(M6, check = "outliers")
```

```
check_model(M6, check = "binned_residuals")
```

```
overdisp_fun(M6)
```

```
## Model 7: Comparison Final Choice between Kea and Corvids
```

```
M7.0 <- glmer(Final_Choice ~ 1+ (1|ID), family = binomial, data =  
df_all)
```

```
check_model(M7.0, check = "outliers")
```

```
check_model(M7.0, check = "binned_residuals")
```

```
overdisp_fun(M7.0)
```

```
M7.1 <- glmer(Final_Choice ~ Species_Group + Test_Condition +  
Target_Weight + (1|ID), family = binomial, data = df_all)
```

```
summary(M7.1)
```

```
check_model(M7.1, check = "outliers")
```

```
check_model(M7.1, check = "binned_residuals")
```

```
overdisp_fun(M7.1)
```

```
as.data.frame(anova(M7.0, M7.1, test="Chisq"))
```

```
### Explorative Analyses ###
```

```
#filter for first trial and seesaw session
```

```
df_T1_ss <- TESTING_Data %>%
```

```
  filter(Test_Condition == "seesaw") %>%
```

```
  filter(Trial_Nr == "1") %>%
```

```
  filter(Species_Group == "kea")
```

```
## MODEL 8: Is the times that the birds experienced beam movement in  
the prep session predictive of their testing success?
```

```
#Null model
```

```
M8.0 <- glm(First_Choice ~ 1, data=df_T1_ss, family="binomial"(link =  
"logit"))
```

```
summary(M8.0)
```

```
check_model(M8.0, check = "outliers", )
```



```

check_model(M8.0, check = "binned_residuals")

overdisp_fun(M8.0)


#Full model

M8.1 <- glm(First_Choice ~ beam_movement_cs + comb_obj_pl + Days_prep
+ Target_Weight + Sex, family="binomial"(link = "logit"),
data=df_T1_ss)

summary(M8.1)

check_model(M8.1, check = "outliers", )

check_model(M8.1, check = "binned_residuals")

overdisp_fun(M8.1)

#PROBLEMATIC ALMOST OVERDISPERSED


#Remove Sex

M8.2 <- glm(First_Choice ~ beam_movement_cs + comb_obj_pl + Days_prep
+ Target_Weight, family="binomial"(link = "logit"), data=df_T1_ss)

summary(M8.2)

check_model(M8.2, check = "outliers", )

check_model(M8.2, check = "binned_residuals")

overdisp_fun(M8.2)

#this one is better! sex doesn't really make a difference in most
models so it should be fine!


#Full-Null-Comparison

as.data.frame(anova(M8.0, M8.2, test="Chisq"))

```

```

#filter for first trial and water session

df_T1_wb <- TESTING_Data %>%

  filter(Test_Condition == "waterbowl") %>%

  filter(Trial_Nr == "1") %>%

  filter(Species_Group == "kea")


## MODEL 9: Is the manipulation time of object inside water predictive
of test success?


df_T1_wb <- df_T1_wb %>% filter(ID != "Kiri") #Filter kiri,
unfortunately lost one video here.


#Null-Model

M9.0 <- glm(First_Choice ~ 1, family="binomial"(link = "logit"),
data=df_T1_wb)

summary(M9.0)

check_model(M9.0, check = "outliers")

check_model(M9.0, check = "binned_residuals")

overdisp_fun(M9.0)


#Full-Model

M9.1 <- glm(First_Choice~object_contact_ws + Days_prep + Target_Weight
+ Sex, family="binomial", data=df_T1_wb)

summary(M9.1)

check_model(M9.1, check = "outliers", )

check_model(M9.1, check = "binned_residuals")

overdisp_fun(M9.1)

```

```

#try to remove sex

M9.2 <- glm(First_Choice~object_contact_ws + Days_prep +
Target_Weight, family="binomial", data=df_T1_wb)

summary(M9.2)

check_model(M9.2, check = "outliers", )

check_model(M9.2, check = "binned_residuals")

overdisp_fun(M9.2)

#better concerning residuals


#Full-Null-Comparison

as.data.frame(anova(M9.0, M9.2, test="Chisq"))

```

## Abstract (DE)

Gewicht als Eigenschaft von Objekten kann von Menschen und nichtmenschlichen Tieren auf zwei Ebenen wahrgenommen werden. Es kann direkt – haptisch - beim Heben und Manipulieren von Objekten erfahren werden, oder auch indirekt - beispielsweise durch visuelle oder auditive Reize rückgeschlossen werden. Studien anhand von Schimpansen, Kea Papageien und auch Neukaledonischen Krähen deuten darauf hin, dass es kontext- und speziesabhängige Unterschiede gibt, die diese inferentielle Wahrnehmung von Gewicht beeinflussen könnten. Neophilie – Eine Anziehung zu neuen Stimuli, und Neophobie – eine Abneigung dagegen, könnten eine wichtige Rolle spielen. Sie beeinflussen, wie verschiedene Spezies explorieren und mit Objekten in ihrer Umgebung interagieren.

In dieser Studie werden Kea (*Nestor notabilis*), Raben (*Corvus corax*) und Krähen (*Corvus corone/cornix*) darauf trainiert, entweder ein leichtes oder schweres Objekt dem Experimentator zurückzugeben. Neophile Spezies wie beispielsweise Kea könnten eine Präferenz haben, haptische Information zu nutzen, während neophobe Spezies wie Raben und Krähen möglicherweise eher visuelle Information nutzen, um das Gewicht von Objekten abzuschätzen. Danach bekommen sie 4 Testbedingungen, in denen visuelle Information entweder kontext- oder objektabhängig variiert. Kea und Corviden benutzten über alle Testbedingungen hinweg häufiger die verlässlichere haptische Information. Wenn die Objekte jedoch noch neu sind, könnten die Corviden eine stärkere Präferenz für das Benutzen visueller Information besitzen, als die Kea. Da aber die Stichprobe der Corviden sehr klein ist, sind diese Resultate vorsichtig zu Interpretieren.