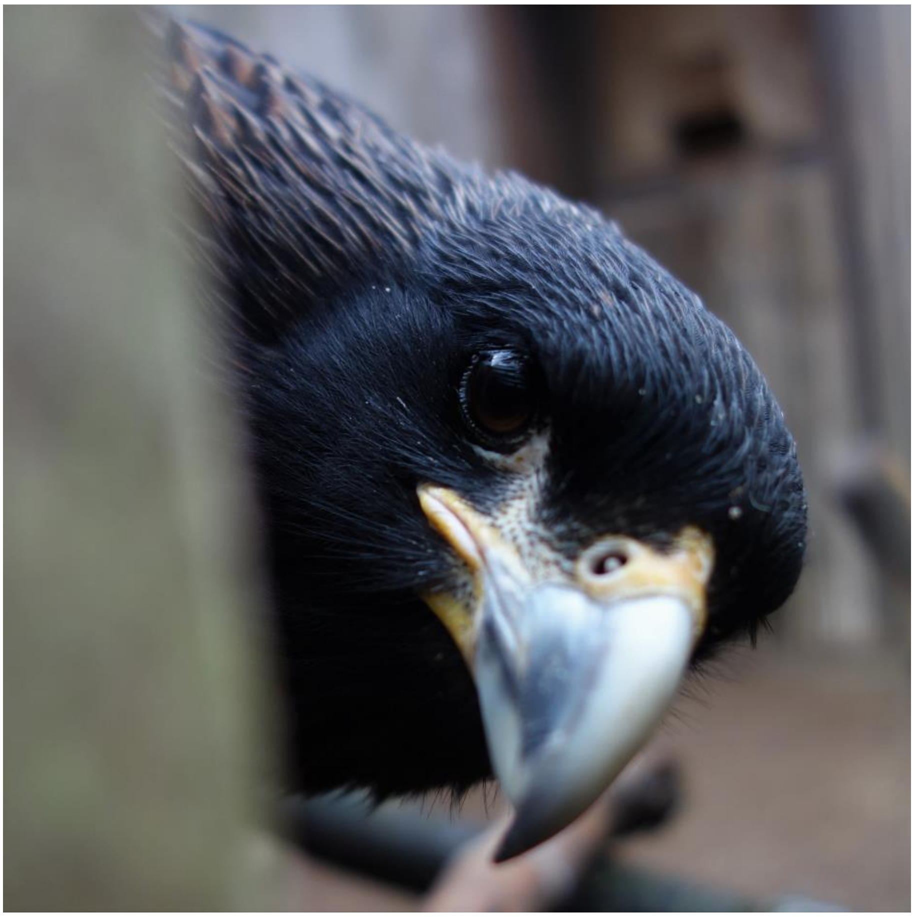
Comparing neophobia, object exploration & problem solving behaviour in Kea (*Nestor notabilis*), Common raven (*Corvus corax*) & Striated caracara (*Phalcoboenus australis*)



Bachelor Thesis

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Eigenständigkeitserklärung

Ich erkläre hiermit, dass ich die vorliegende Bachelorarbeit selbstständig unter Anleitung verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.

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ABSTRACT

In the here presented work similarities and differences amongst Common raven (*Corvus corax*), Kea (*Nestor notabilis*) and Striated caracara (*Phalcoboenus australis*) in neophobia, object exploration behaviour and problem solving abilities are compared. Ravens and keas are well known for sophisticated cognitive abilities and are extensively studies in ethological research. For the striated caracara no literature on their neophobia or cognitive capacities exists so far.

All prominent examples of high intelligence in birds fall either into the order of Passeriformes (passerines) or into the order of Psittaciformes (parrots). Recent phylogenetic reorganisation of taxonomy placed the Falconiformes (falcons and caracaras) as a sister group of the Psittaciformes and Passeriformes in the Eufalconimorphae clade. It is therefore of great interest to find out, if the newly established phylogenetic relation is matched by advanced cognitive abilities, too.

To test for (non-)neophobic behaviour the birds willingness to feed with an odd novel object next to their food was examined. In the object exploration test the birds were confronted with six inedible objects they had never seen before. Three of them natural (e.g. a snail shell), three of them unnatural (e.g. a transparent plastic lid). For the problem solving test the duration necessary to obtain food from a box was measured. Five different box setups were implemented featuring several levels of difficulty.
The results of the neophobia test revealed that both, keas and striated caracaras, are clearly non-neophobic, whereas ravens displayed a high level of neophobia. A surprising finding was that all three species display a similarly high level of object exploration behaviour. But the striated caracaras showed a preference for unnatural objects and ravens showed a preference for natural objects. The findings of the problem solving test suggest that all three species have advanced physical cognitive abilities. The keas performed significantly better than the striated caracaras, and the ravens showed a tendency to perform faster than the striated caracaras.

This work presents the first assessment of personality traits for the striated caracara and reports advanced problem solving abilities for all three species. Striated caracaras showed to be interesting candidates for cognitive research in raptors.

ZUSAMMENFASSUNG

In der hier vorliegenden Arbeit werden Gemeinsamkeiten und Unterschiede in Neophobie, Objekt-Explorationsverhalten und Problemlösefähigkeiten zwischen Kolkraben (*Corvus corax*), Keas (*Nestor notabilis*) und Falklandkarakaras (*Phalcoboenus australis*) verglichen. Kolkraben und Keas sind bekannt für stark ausgeprägte kognitive Fähigkeiten und werden in der ethologischen Forschung umfangreich untersucht. Für den Falklandkarakara existiert bisher jedoch keine Literatur über Neophobie oder kognitive Leistungen.

Alle herausragenden Beispiele hoher Intelligenz bei Vögeln stammen entweder aus der Ordnung der Passeriformes (Sperlingsvögel) oder aus der Ordnung der Psittaciformes (Papageien). Neuere phylogenetische Umstrukturierung in der Taxonomie der Aves stellten die Falconiformes (Falken und Karakaras) als eine Schwestergruppe der Psittaciformes und Passeriformes in die monophyletische Gruppe der Eufalconimorphae. Es ist daher von großem Interesse, zu untersuchen, ob sich die neu etablierte phylogenetische Verwandtschaft auch in ausgeprägten kognitiven Fähigkeiten widerspiegelt.

Um auf (nicht-)neophobes Verhalten zu testen wurde die Bereitschaft der Vögel überprüft Nahrung in Anwesenheit eines unbekannten, abschreckenden Objektes aufzunehmen. In dem Objekt-Explorationstest wurden den Vögeln sechs nicht essbare Objekte präsentiert. Drei von ihnen natürlich (z.B. ein Schneckenhaus) und drei von ihnen unnatürlich (z.B. ein transparenter Plastikdeckel). Für den Problemlösetest wurde die Zeit gemessen, die die Vögel brauchten, um an Nahrung in einer Kiste zu gelangen. Dabei wurden fünf verschiedene Box-Setups mit unterschiedlichen Lösungsschwierigkeiten genutzt.

Im Neophobietest zeigten sowohl die Keas, als auch die Falklandkarakaras eindeutig nicht-neophobes Verhalten, wohingegen die Raben einen hohen Level an Neophobie aufwiesen. Eine überraschende Erkenntnis war, dass alle drei Arten einen ähnlich hohen Level an Explorationsverhalten aufwiesen. Allerdings zeigten die Falklandkarakaras eine Vorliebe für unnatürliche und die Kolkraben eine Vorliebe für natürliche Objekte. Die Ergebnisse des Problemlösetest legen den Schluss nahe, dass alle drei untersuchten Arten ausgeprägte physische Problemlösefähigkeiten aufweisen. Die Keas schnitten signifikant besser ab, als die Falklandkarakaras und die Raben zeigten eine Tendenz, schneller als die Falklandkarakaras abzuschneiden.

Diese Arbeit stellt die erste Beurteilung von Persönlichkeitseigenschaften der Falklandkarakaras dar und zeigt ausgeprägte Problemlösefähigkeiten für alle drei Arten. Falklandkarakaras stellten sich als interessante Kandidaten für Kognitionsforschung bei Greifvögeln heraus.

1 INTRODUCTION

1.1 Birds in cognitive and behavioural research

The view on birds intelligence has changed dramatically over the last decades and the general view on birds went from proverbially ‘bird brains’ to calling corvids ‘feathered apes’ (Emery, 2004). Now there is an extensive amount of literature about cognitive behaviour in birds and it is no longer a question that some birds have distinct cognitive skills, see e.g. (Emery, 2006; Lefebvre, Licolakakis, & Boire, 2005; Shettleworth, 2010). Cognitive research in birds concentrates on few species and often focuses on specific areas of interest within species e.g.: domestic Pigeons (*Columba livia domestica*), mainly for visual perception; Common raven (*Corvus corax*), for general cognition; New Caledonian crow (*Corvus moneduloides*), mainly tool-use; Keas (*Nestor notabilis*), general cognition, and African grey parrot (*Psittacus erithacus*) mainly for language learning and cognition.

The brains of some bird families have adapted to solve a wide range of socio-ecological problems, such as living in large individualized societies, like anthropoid primates do (Emery, 2004). It has been shown for Neotropical parrots that large brain size facilitates abilities for innovative behaviour, learning and behaving flexibly (Schuck-Paim, Alonso, & Ottoni, 2008). Other studies have shown that Psittaciformes possess similar, or even larger relative brain and telencephalic volumes than primates (Iwaniuk, Dean, & Nelson, 2005). There is no data yet to generalize correlation of relative brain size and advanced cognitive abilities for all birds. But it has been shown lately that bird brains are not so much different from mammal brains, as it has been thought for more than 100 years. The lack of any brain structure equivalent to the cerebral cortex in mammals, led to the wrong assumption that bird brains are poorly developed. It turned out, they are just a little differently organized. The traditional naming of the brain structure of birds suggested that the majority of the avian telencephalon arises from the striatum (including functions like reward cognition and reinforcement), which is comparably small in mammals. In mammals the largest part of the telencephalon is the pallium housing the palaeocortex, the archicortex and the neocortex amongst other structures. The neocortex carries out the processing of sensory information, motor control and sensorimotor learning. The avian pallium, has traditionally been thought to be tiny, but new research shows that the majority of the avian brain has pallian origin (Jarvis, Gtinttirktin, & Bruce, 2005).

Thus, it has been shown that some birds have numerical concepts and very good discrimination abilities (Swenson, 1970). And unlike mammals, social learning was confirmed for all birds ever tested or studied (Lefebvre & Bouchard, 2003). Also tool-use has been reported for at least 104 species (Lefebvre et al., 2005). For many more species, however, only anecdotal knowledge exists so far. Astonishing findings like the fact that pigeons are able to distinguish benign and malignant human breast histopathology images after short training as well as medical personal after year long training (Levenson, Krupinski, Navarro, & Wasserman, 2015) illustrate that cognitive research in birds is a field of behavioural biology that holds much to learn. And might possibly lead to a better understanding of our own visual perception or intelligence.

1.2 Neophobia & Object exploration

With around 9000 species of birds (Perrins, 2003) the class of aves has an immense diversity, populating nearly every niche on all five continents. Some birds have evolved to match very specific living situations. This immense diversity is also resembled by a large diversity in traits of specific behaviour and personality. It is desirable to understand the different abilities, behavioural and cognitive traits that determine the various successful strategies within this family. Comparative cognition research is a branch of ethology, which focuses on the differences and similarities between species or groups. The knowledge of a bird’s behaviour is crucial for planning and interpreting the outcome of an experiment. For example not solving an experimental setup might not result from minor cognitive abilities, but can result from ‘fear of something new’, too. Following two of these parameters of personality that are of interest for this thesis are described.

Neophobia is the fear of anything new, vice versa neophilia is the strong interesting in anything new. Yet these two measures do not necessary contradict each other. In fact these two traits are different axes of personality, rather than diametrical opposites: A test for neophobia measures the ability to overcome fear whilst taking a risk with an external motivation (food) and neophilia measures the intrinsically motivation towards novelty without reward (Greenberg & Mettke-Hofmann, 2001). It has been object of discussion if a relation exists between neophilia and neophobia, but it appears not to be true (Mettke-Hofmann, Winkler, & Leisler, 2002).

These two parameters differ between species and groups of birds. For example adult ravens (*Corvus corax)* show very strong neophobic behaviour (Heinrich, 1988), whereas keas (*Nestor notabilis)* range on the opposite pole, showing no neophobic behaviour at all, and display very neophilic behaviour at the same time (Keller, 1975). That ravens show so strong neophobic behaviour seems surprising, since neophobia has been linked to narrow ecological specificity (Greenberg, 1990) which is clearly not the case for this species. In fact ravens may be the most widely distributed species amongst passerines (Bent, 1988). However, young ravens are very different in their exploration behaviour and contact almost all unknown objects. This trial and error learning soon changes towards mainly food contacts and at the age of around one year they do not contact anything unknown anymore. During this short period a huge variety of stimuli of potential food is rapidly learned thus rendering the need of exploring unknown objects unnecessary for the rest of their lives. Neophilic behaviour can be reinduced in adults by starvation (Heinrich, 1995b).

Neophilia characterizes the intrinsic motivation towards novel objects, novel habitats, novel food sources and so on. It is often tested by introducing novel objects to the birds and measuring their response towards these objects. Novel object exploration is a popular test in behavioural biology since it possesses several benefits: the setup is easy and its implementation is relative short, thus allowing larger sample size; the test is easy to compare between species since no motivational manipulation (e.g. reward, aversive motivation or deprivation of food or water) is needed; the testing situation is less artificial than many other testing setups (Blaser & Heyser, 2015). Object exploration tests measure the intrinsic response of the testing subject towards novelty, this can be exploration or avoidance (Hughes, 1997). Naturally, different characteristics in behaviour towards novel objects shape the lifestyle of an animal in how it is able to acquire novel sources of food or establish in new environments. Thus neophilia is a dimension of personality that can, like aggression or boldness, influence reproductive success (Smith & Blumstein, 2008) and may underlie natural selection. Some behavioural phenotypes have been shown to be genetically or epigenetically heritable (as for humans) and may affect exploration behaviour, dispersal or risk-taking (Dingemanse, Both, van Noordwijk, Rutten, & Drent, 2003; van Oers, Drent, de Goede, & van Noordwijk, 2004) etc. in Great tits (*Parus major*).

1.3 Problem solving

Testing for neophobic behaviour and a bird’s interest into novel objects gives basic information about the bird’s species general behavioural traits, or the bird’s personality. To test for differences in cognitive skills more advanced setups have to be applied. Cognitive behaviour fans out over several domains, such as physical intelligence (sometimes called ‘folk-physics’, i.e. the understanding of objects and their spatial, causal and numerical relations, tool-use falls in this category, too), social intelligence (knowing about other individuals and their actions, intentions and relationships e.g. understanding social structures), memory (e.g. remembering many different sources of food and being able to distinguish them) and so on. A lot of literature exists about cognition in birds. One common approach for testing cognition and physical intelligence is to test the abilities to solve a novel problem. In general there are several options to solve a novel problem e.g.: Trial and error learning can lead to success, without implying sophisticated cognitive abilities. But persistence is needed, which can be induced by external motivation e.g. food or water. Another option is social learning: one individual watching another performing in an experimental setup and thereby learning to imitate the motoric pattern for successfully solving a setup (Fritz & Kotrschal, 1999). Or insight, which has been defined as 'the sudden production of a new adaptive response not arrived at by trail behaviour or as the solution of a problem by the sudden adaptive reorganization of experience' (Thorpe, 1956). Meaning that the steps necessary to solve a novel task have to be planned mentally before performing any action. An experiment to test insightful problem solving is the string-pulling experiment, where animals can choose between several strings that can be crossed or can have changes in colour. Only one of them has food attached as a reward (Thorpe, 1943; Vince, 1958). African grey parrots (*P. erithacus*) showed the ability to solve this setup, too, but surprisingly, individuals, which had received language training, did not succeed in the setup any more but demanded the object vocally (Pepperberg, 2004).

Another experiment to test problem solving abilities is a box-like setup: food is placed in a box, this box is closed and the birds have to perform a specific task e.g. sliding, twisting, pushing or pulling parts of the setup, or a combination of these tasks to obtain the food. An advantage of the box-setup is that it can be easily modified and made more difficult. Also the integration of tool-use is possible. On the other hand this flexibility is a drawback in terms of comparability. The box can be build out of transparent material (Auersperg, Huber, & Gajdon, 2011; Auersperg, von Bayern, Gajdon, Huber, & Kacelnik, 2011) or opaque material (Fritz & Kotrschal, 1999). Both setups test for problem solving abilities, but in a transparent setup the individuals do not have to learn or remember that food is presented into the box. However they might have to be able to inhibit the immediate impulse to go for the food and have to focus on solving the setup instead to obtain the reward. In an opaque setup no distraction by the food is possible during problem solving, but object permanence is necessary to grasp that the food is in the box despite being not visually accessible. Piagetian object permanence is 'the ability to keep track of objects and individuals that are not currently available to perception' (Emery, 2006). Stage 4 of object permanence requires the individual to be able to form a representation of a fully hidden object (Piaget, Cook, & Norton, 1952). Object permanence is also a necessary prerequisite for caching food. For *C. corax* (Bugnyar, Stöwe, & Heinrich, 2007), *N. notabilis* (Rahde, 2014) and a couple of other parrots (Pepperberg & Funk, 1990) object permanence up to the uppermost stage 6 has been proved. Humans achieve this stage at around two years of age (Shettleworth, 2010).

1.4 Zoos and research

To compare the behaviour and cognition of different species controlled experimental conditions are a prerequisite, as differences in results could also be due to different testing conditions. However, most species live in diverse natural habitats and conducting experimental research on free living subjects is mostly very difficult. Therefore, comparative research often focuses on research facilities or zoos, where different species are housed under similar conditions and easy to access.

Zoo like institutions existed as early as around 3500 B.C. in Egypt (Rose, 2010), but the focus of these institution has extended increasingly in recent years, from mere display of animals to research, education and species conservation. The Zoo Heidelberg for example currently participates in 16 'Europäische Erhaltungszuchtprogramme' (EEPs), including birds like the Northern bald ibis (*Geronticus eremita*) which is already extinct in Europe, the American flamingo (*Phoenicopterus rube*) and several species of owls. Also *in situ* conservational projects are supported (Zoo-Heidelberg). The 'Zooschule' offers a variety of educational programs and the Zoo gives external researchers access and support to work with its animals. The animals can benefit indirect, since new insights may result in better conservation of their species in the wild or direct by enrichment. Behavioural and cognitive research itself may enrich their life or result in the development of new enriching objects. Other than in medical research in non-public institutes the animals wellbeing has priority and no armful research is conducted at zoos.

All of the three species, which are object of research in this thesis (ravens, keas, caracaras) are commonly held in Europe with the striated caracara being rarest: The common raven is held in 63 zoos or animal-parks around Germany, and in 89 other locations of the European Association of Zoos and Aquaria (EAZA), keas are rarer with 19 locations within Germany and 35 across the rest of the EAZA. The striated caracara is rarest with 9 locations in Germany an 42 across the rest of EAZA (Zootierliste, 2015). The latter two species are listed in CITES II (see 2.3 Nestor notabilis and 2.4 Phalcoboenus australis) and for the kea an EEP is implemented. Two possibilities exist for holding birds in Zoos: the birds can be held in aviaries, this is expensive and the aviaries are usually small, but the birds are able to fly. The second option is to deflight them (either temporary or permanently removal of specific feathers) the birds do not have to be held in cages then, but complications can result from the procedure of deflighting (Hesterman, Gregory, & Boardman, 2001). It is object of discussion which of the two practices is better for the birds in terms of welfare. This might depend on the species, too. None of the three species tested in this thesis are deflighted in the Zoo Heidelberg, which supports natural behaviour.

Furthermore, behavioural research is crucial for understanding the differences in the personality of species or individuals, which helps to develop strategies to increase their welfare. The stress level of a bird, as indicator of wellbeing, can be measured by the level of the hormone corticosterone directly. But great differences exist amongst individuals (Cockrem, 2007). Mere investigation of biochemical parameters does not give a complete picture of the individuals wellbeing. But a close investigation of the animals behaviour for answering questions about the animals health and the gratification of all its needs might give better results, than ‘hard science’ methods and it is less invasive (Dawkins, 2004).

In Zoos a diverse offer of different food, activity and social interaction is necessary to prevent stereotypies, especially for highly intelligent species e.g. apes or parrots. Stereotypies are ‘abnormal repetitive, unvarying, and functionless behaviors that are often performed by captive and domesticated animals’ (Garner, Meehan, & Mench, 2003). Stereotypies are unwanted, since they do not represent natural behaviour and are associated with deficient holdings. Enrichment reduced stereotypic behaviour significantly within four day in Orange-winged Amazon parrots (*Amazona amazonica*) (Meehan, Garner, & Mench, 2004). Enrichment in the Zoo Heidelberg is applied regularly: The birds occasionally receive closed cupboard boxes that are filled with crushed paper and small pieces of food. The box has to be destroyed and emptied out in order to attain the food. Also unfamiliar objects such as tennis balls are introduced to the aviaries. Sometimes excessive food is given, which supports caching behaviour, or food is presented on unusual locations (e.g. an apple speared on a branch). The kea’s aviary contains a hanging platform, sometimes food is placed on this moving platform, similarly the ravens aviary holds a swing. The caracaras aviaries are not enriched, but this is a temporary solution. The female receives regular training (see 3.1.3 Striated caracaras).

Thus, zoos offer a good opportunity for behavioural and cognitive studies. The animals benefit in a better understanding of their needs and more appropriate living conditions. For example, the here presented work gives information about the birds preferences and suggests beneficial design of new enrichment (see 5.1.5 Suggestions for enrichment).

1.5 Aim of the study & Predictions

In this thesis I aim to conduct comparative behavioural research between common ravens (*Corvus corax*), keas (*Nestor notabilis*), and striated caracaras (*Phalcoboenus australis*). I am going to conduct experiments to classify the level of neophobia, object exploration behaviour and problem solving behaviour for these species. Comparing these species is of special interest, as for ravens and keas a huge amount of literature already suggests that they will be ideal model organisms e.g. for the neophobia test, as they show extremely different neophobic behaviour. In contrast, next to nothing is known about the neophobia and cognitive abilities of the striated caracaras. Testing all three birds with the same setups allows it to compare the three species amongst each other. Also the results of the ravens and keas can be compared to literature and thereby serve as a reference for the caracaras.

As described in 1.2 Neophobia & Object exploration common ravens (*C. corax*) show very strong neophobic behaviour and keas (*N. notabilis*) show no neophobic behaviour at all. For the striated caracara (*P. australis*) no data exists so far, but the Chimango caracara (*Milvago chimango*), which belongs to the same subfamily shows little neophobic behaviour (Biondi, Bo, & Vassallo, 2010). As the striated caracara is a closely related predator without natural enemies, it could be suggested that it, too, will show little neophobic behaviour. Furthermore, it has been reported that wild living *P. australis* are exceptionally tame (Catry, Lecoq, & Strange, 2008), also contradicting strong neophobic behaviour. In a neophobia test a bird with very little neophobic behaviour will go for the food without delay, where else a bird with strong neophobic behaviour might take some time to adapt to the different situation of feeding.

Object exploration behaviour has been described for ravens, as well, as for keas. In ravens object exploration behaviour and neophilia are linked to age (Heinrich, 1995b). Keas display strong attraction towards novel objects (Huber & Gajdon, 2006; Huber, Rechberger, & Taborsky, 2001). Again no data exists for striated caracara (*P. australis*). However, the Chimango caracara (*M. chimango*), shows great interest into exploring novel objects. But differences between youngsters (more explorative) and adults (less explorative) exist. Also explorative behaviour is not linked to the level of neophobia in the Chimango caracara (Biondi et al., 2010).
Testing the reactions towards natural and unnatural objects is of great interest, since the habitats of all three investigated species overlaps at least to some extend with human settlings. Therefore unnatural objects have become objects, which all these species encounter regularly. Keas often visit Ski-resorts during wintertime for feeding and play (Bond & Diamond, 1992), ravens have adapted well for a live in human settlements (del Hoyo, Elliott, & Cristie, 2009) and benefit greatly from human leftovers. The striated caracara does scavenge, too, but to a smaller extend (del Hoyo et al., 1994). Reaction towards unnatural objects might give information about the acquisition of novel food sources or the design of enrichment for the birds.

A basic knowledge about the level of neophobic behaviour and object exploration behaviour is crucial for more advanced experimental setups (see 1.2 Neophobia & Object exploration). To find out more about cognitive abilities of the three species in the domain of physical intelligence a problem solving experiment is applied. For ravens and keas tool-use and problem solving have already been reported and a high level of physical intelligence is suggested (Auersperg, Huber, et al., 2011; Emery, 2006; Huber & Gajdon, 2006). Again no literature exists about the striated caracara, and only little is known for the closely related chimango caracara (Biondi et al., 2010). In general comparative studies among birds are rare. As described in 1.3 Problem solving there are several possibilities for solving an experimental setup, ranging from trial and error learning to insight. Insightful or at least rapid problem solving behaviour has been demonstrated for ravens (Heinrich, 1995a) and keas (Werdenich & Huber, 2006) in string pulling experiments. The only raptors ever tested in a similar setup are Harris hawks (*Parabuteo unicinctus*), they were able to solve the setup and applied similar techniques as corvids and parrots, but needed in average 8 min. No insightful or rapid problem solving behaviour could be observed (Colbert-

White, McCord, Sharpe, & Fragaszy, 2013). Falling into different orders the striated caracaras and harris hawks are not closely related, but share a social lifestyle and a similar habitat.

The box-like setup has several benefits (see1.3 Problem solving) and is applied for this thesis. In the here presented problem solving experiment (see 3.4. Problem solving test) the food is visible only in some trials, which makes object permanence of stage 4 or higher a necessary prerequisite. Very little species have been tested for object permanence so far. Nonetheless a minimum of stage 4 can be expected for any caching bird (Pepperberg & Funk, 1990), this includes caracaras. It is therefore predicted that all three species have the capacity to solve the problem solving setup, but will perform differently well.

1.5.1 Working hypotheses

Based on literature and prior observations the following hypotheses are postulated about the outcome of the neophobia test, the object exploration test and the problem solving test:

i) Keas are not neophobic, raven are neophobic, caracaras range in between but show clear tendency towards non-neophobic behaviour.
ii) Keas and caracaras show great explorative behaviour, raven show little explorative behaviour.
iii) The exploring behaviour of the species differs in exploration time, number of contacts and preference for natural or unnatural objects.
iv) Caracaras are able to solve advanced experimental setups similarly to keas and raven.
v) To solve a more complicated experimental setup will take more time for any species.
vi) There are differences in the ability to solve complex experimental setups between the species.

2 GENERAL INFORMATION ABOUT THE SPECIES

2.1 Taxonomy

In this work three different species of birds were investigated: *Corvus corax*, *Nestor notabilis* and *Phalcoboenus australis*. The taxonomy of birds is, like many other taxonomies, in constant change since genetic research becomes constantly more advanced. A sister relationship between Passeriformes and Psittaciformes was established recently (Hackett et al., 2008; Suh et al., 2011). The former order of Accipitriformes containing nearly all diurnal birds of prey has been divided since the Falconiformes have been shown to be related to the Passeriformes and Psittaciformes (Hackett et al., 2008; Suh et al., 2011). The eagles and New World vultures were excluded from the Falconiformes and placed in Acciptrimorphae (Jarvis et al., 2014). The three investigated species belong to orders, which are now grouped together in the new Eufalconimorphae clade. The Passeriformes and Psittaciformes are grouped together into the Psittacopasserae (Suh et al., 2011). In **tab. 1** the classification after IUCN is given, including only the standard taxonomic ranks.

Within the species *C. corax* three clades with little genetic exchange exist ('Holarctic clade', 'California clade' (Omland, Tarr, Boarman, Marzluff, & Fleischer, 2000) and 'Canary island raven' (Baker & Omland, 2006)) due to geographical barriers. Eleven subspecies exist, which differ mainly in size, and colour shade of plumage. (del Hoyo et al., 2009).

Taxonomy

Kingdom:	Animalia		
Phylum:	Chordata		
Class:	Aves		
Order:	Passeriformes (passerines)	Psittaciformes (parrots)	Falconiformes (falcons and caracaras)
Family:	Corvidae (corvids)	Strigopidae (kakapo)	Falconidae (falcons)
Genus:	*Corvus*	*Nestor*	*Phalcoboenus*
Species:	*corax*	*notabilis*	*australis*
Taxon name:	*Corvus corax* Linnaeus, 1758 (Common raven)	*Nestor notabilis* Gould, 1856 (Kea)	*Phalcoboenus australis* Gmelin, 1788 (Striated caracara)

Tab. 1: Taxonomy of the three examined species: Common raven (IUCN, 2014), Kea (IUCN, 2012a) and Striated caracara (IUCN, 2012b).

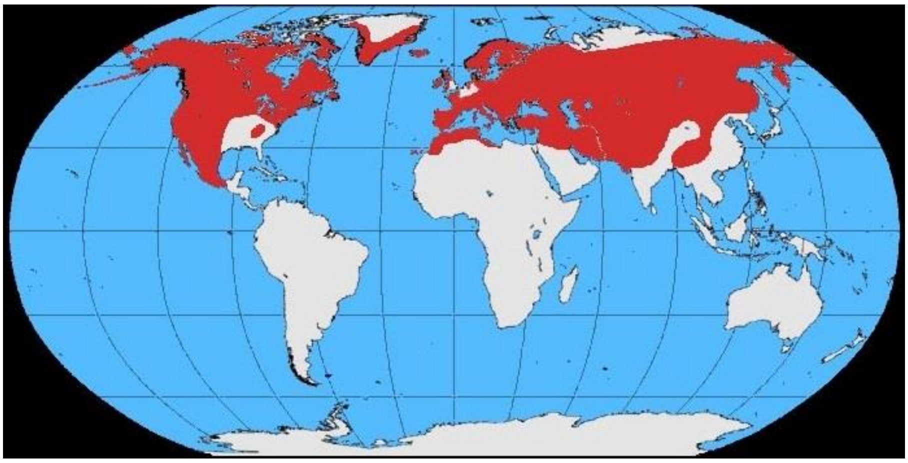
2.2 Corvus corax – Common raven

IUCN: Least concern; CITES: non (IUCN, 2014)

An average adult common raven is 58 – 69 cm in height with a weight of 585 – 2000 g, this makes them the largest living passerine bird species. Maximum reported life span in the wild is 13.3 years, but 40 – 80 years in captivity (del Hoyo et al., 2009).

2.2.1 Habitat & diet

C. corax is a habitat generalists, which populates nearly the entire northern hemisphere (see **pic. 1**) settling in habitats such as open coast, desert, mountains, temperate rain forests and human settlements. They are opportunistic scavengers, which are associated with large carnivores, birds of prey and humans. Their number in the wild is increasing (IUCN, 2014), since they profit from human's wasteful food use and learned to exploit novel food sources like roadkills. *C. corax* eats a huge variety of animals, including other birds and sometimes their nestlings, small mammals, fish, invertebrates and plants such as fruits, sea-weed, and grain. And nearly any kind of carrion, waste, slaughterhouse offal, dung. *C. corax* is able to recognize people, which carry guns and investigate locations of shots but food is located by sight mainly, rather than by sound. Smell might play a subordinate role for close range, too. They cache food and long-lasting food like eggs might be stored for extended period but *C. corax* does not depend on stored food during winter (del Hoyo et al., 2009). Studies have shown, that *C. corax* is able to remember, whether and which other individuals are watching them whilst caching and try to prevent them from watching or might come back later to retrieve the cached food to hide it somewhere else (Shettleworth, 2010). Corvids do use tools like sticks to obtain food and drop nuts or shellfish from higher altitudes on hard ground. However only one evidence exists for tool use in *C. corax* described by Holmberg in: (Boswall, 1977; Scott, 1974) using fishing lines to get fish under ice.



Pic. 1: Distribution of the Common raven *Corvus corax; (Hogroth, 2015)*

2.2.2 Reproductive behaviour

C. corax is monogamous, forming presumably life long bonds. Both sexes build a nest together in 3 – 30 m height on trees or steep cliffs on artificial structures nests could be observed even higher. Good nesting sites are reused every year, some for more than a century. The 1 – 8 eggs (4 – 6 is typical) are incubated by the female and occasionally by the male for 20 – 25 days. The reproduction success of couples which have been staying together for long time is higher, than that of newly formed couples. The hatchlings stay with their parents for a couple of weeks or even month, before leaving parental territory in late summer (del Hoyo et al., 2009).

2.2.3 Additional information

C. corax uses complex communication with more than 20 different calls known for specific functions, 79 call types could be discriminated spectrographically, additionally these are modulated in pitch, frequency and intensity to serve many purposes according to different context. For example the frequency of a call indicating the approach of a predator may change according to the immediate danger. They are able to mimic sounds and learn them partly from partners and same sex individuals in close range (del Hoyo et al., 2009). *C. corax* is on second position of brain size/body size ratio amongst corvids only surpassed by the American Crow (*Corvus brachyrhynchos*), both ratios are closer to the range of mammals and most primates, than to the rest of the birds (del Hoyo et al., 2009).

2.3 Nestor notabilis – Kea

IUCN: Vulnerable; CITES II (IUCN, 2012a)

An average adult kea is 48 cm in height with a weight of 922 g, there is no sexual dimorphism aside from a longer bill in males (del Hoyo, Elliott, & Sargatal, 1997). The oldest kea reported in wild was 20 years, the average life expectancy is 5 years (Heather & Robertson, 1997).

2.3.1 Habitat & diet

N. notabilis lives in the mountains of south-west New Zealand (see **pic. 2**). The natural habitats are forests and subalpine scrublands flanking higher mountains. They normally occupy habitats between 600 and 2000 m but migrate with changing seasons. Higher in autumn to feed on wild berries, which grow in high altitude and gradually descend, as the weather becomes harsher. Their ability to adapt for a life in alpine area is unique amongst the rest of the parrots. *N. notabilis* live on the ground and fly infrequent, manly to cover altitude movements, but are capable of persistent flight like most other parrots (del Hoyo et al., 1997). Their diet changes throughout the year. The typical summer died consists of tree shoots and shrubs like Mountain flay (*Phorimum colensoi*), later berries like the Snow totara (*Podocarypus nivalis*). Additional *N. notabilis* feeds on fruits and leafs of several other plants throughout the year whenever available. The elongated mandible is well adapted to dig for roots. This diet is improved by flesh of carcasses and food from rubbish-dumps. Keas can be seen at ski-resorts frequently to feed on human leftovers (del Hoyo et al., 1997).

Pic. 2: Distribution of the Kea *Nestor notabilis* in New Zealand (KimvdLinde, 2015)

2.3.2 Reproductive behaviour

Unlike many other Psittacidae *N. notabilis* is polygynous with one male being attached with up to four females, the male feeds them during breeding. Breeding occurs all year around expect late autumn, high season is between Julie and January (summer). The nest is built below ground level or under tree roots, rocks or hollow logs. The 2 – 4 eggs are incubated for 3 – 4 weeks. The nestling period is 13 weeks. Although *N. notabilis* is polygynous there are generally too many females, mortality amongst males is very high in early life and only 10% of the born males reproduce at least once (del Hoyo et al., 1997). No recent data exist about population size, but it was estimated, that the population of mature individuals is around 3,300 and the total number around 5,000 (Heather & Robertson, 1997).

2.3.3 *Additional information*

Playing behaviour can be observed frequently either solitary or socially, sliding in the snow, swimming on their back and so on is partially for training anti-predator skills but seems to be ‘just for fun’ as well (del Hoyo et al., 1997). *N. notabilis* has a brain size/body size ration greater than 1 SD. above average than what was predicted for its body size (Emery, 2006).

2.4 Phalcoboenus australis – Striated caracara

IUCN: Near threatened; CITES II (IUCN, 2012b)

An average adult caracara is 53 - 65 cm in height with a weight of 1187 g, sexual dimorphism is not very distinct but females are generally bigger (del Hoyo et al., 1994).

2.4.1 *Habitat & diet*

Falconids are found throughout the world except for Antarctic and high Arctic. They inhabit various habitats such as cities, deserts and dense tropical forest, however, all the species of caracaras are exclusive to South America (with two exceptions occurring also in Central America). Much more important than the habitat is the structure of the habitat since falconids need specific structures for nesting. *P. australis* can be found on small islands in the extreme south of Southern America, such as the Falkland Island, New Island, Staten Island, Navarino and Cape Horn (see **pic. 3**). In fact *P. australis* has the southernmost breeding distribution of all birds of prey (del Hoyo et al., 1994). Caracaras typically walk on the ground when searching for food or scavenge, both with a high success rate, catching during flight is uncommon. They are omnivorous and their spectrum of food exceeds that of the rest of the family. The diet covers that of falconids but is extended to carrion, insects and discarded waste. But *P. australis* frequently visit colonies of seabirds to steal nestlings, most often from Thin-billed prions (*Pachyptila belcheri*) or sometimes penguins (Catry et al., 2008). Occasionally food is searched in urban area and in the tidal zone. Caching food is common for most of the falcon species, as for *P. australis*. Caches are hidden in relative obvious locations, often close to the nest (del Hoyo et al., 1994).

Pic. 3: Distribution of the Striated caracara *Phalcoboenus australis* in South America (del Hoyo, Elliott, & Sargatal, 1994)

2.4.2 *Reproductive behaviour*

P. australis prefers steep and rocky cliffs with many shelters and holes for nesting. Occasionally they form loose colonies. In average 2-3 eggs are laid, the fledglings hatch after ca. 8 weeks. During breeding season the female is depending on the male for food but supports herself from caches, too. In the first half of breeding the male supports the nestlings exclusively afterwards the female flies out for short periods (del Hoyo et al., 1994). Falconidae are monogamous (Wittenberger & Tilson, 1980), however there are some exceptions, namely some caracaras employ alloparenting strategies, for *P. australis* no data exists so far about monogamy and duration of partnership.

2.4.3 Additional information

A total of 500 breeding pairs is estimated to live in the wild, the population is small and therefore potentially easy vulnerable, but considered to be stable (Woods, 2007). Caracaras, especially of the genus *Phalcoboenus* are relative vocal animals which declare their territory by loud calls. The calls are comparably simple and unspecialized (del Hoyo et al., 1994).

3 MATERIAL & METHODS

3.1 Subjects

3.1.1 Keas

Female kea: Maggie; ♀
Birthdate: Jan. 15th 2014 in Vogelpark Marlow; lives at Zoo Heidelberg since Oct. 7th 2015 (Zoo-Heidelberg, 2015c)
Male kea: Crusty; ♂
Birthdate: Apr. 27th 2013 in Zoo Heidelberg; lives at Zoo Heidelberg since birth (Zoo-Heidelberg, 2015d)

The two keas are housed in a 10 m x 6 m x 3 m (60 m²; 180 m³) enriched aviary containing a small pond, some small trees and a swing. The aviary has no covered retreat but a small roofed area and is partially shaded by a big fir. Two feedings are conducted daily, one in the morning, usually before 9 am consisting of fruits, vegetables and nuts and a second smaller meal around 2.30 pm containing only some nuts, seeds and sometimes larvae. The first meal contains excessive food so that even in the late afternoon some food is left for feeding. Sometimes enrichment is added to the second meal e.g. the nuts are wrapped in paper which is then hidden into a large cupboard carton.
Maggie, the female, just recently arrived at Zoo Heidelberg. She replaced Crusty's mother for the purpose of breeding. Crusty is behaving dominantly towards here, often chasing her away from the feeding bowl (two bowls were introduced temporarily to diminish tension). However, their relationship steadily improved during the testing period and is, according to the keepers, much better than between Crusty and his mother. Maggie is very much focused on humans and shows no fear at all. She usually investigates everything interesting on the keepers clothes (hair ties, belts, keys, shoe laces), she also tries to take food out of the keepers pockets, if she could observe them taking food out of them. She regularly sits on the shoulders of the keepers. Crusty, who did not show this kind of action, started developing a more active behaviour towards the keepers.

3.1.2 Ravens

Female raven: Ivan; ♀
Birthdate: between Jan. 1st 2008 and Jan 1st 2010 in private collection; lives at Zoo Heidelberg since May 10th 2009 (Zoo-Heidelberg, 2015e)
Male raven: Randall; ♂
Birthdate: between Dec. 1st 2010 and Feb. 1st 2011 in Universität Bielefelt, Department of Ethology; lives at Zoo Heidelberg since Nov. 30th 2011 (Zoo-Heidelberg, 2015f)

The two ravens live in a 3.5 m x 7.1 m x 2.7 m (24.9 m²;67.1 m³) aviary containing a swing and a roofed area, there is no retreat from the visitors. They are feed once daily between 9 am and 10 am. The diet varies on daily basis to match the omnivorous diet of *C. corax*. The food always contains some vegetables or fruit and animal protein in the form of mice, rat(babies), chicks, fish, mussels or egg, occasionally hornbill-pellets or dog food is added. Ivan was bought by the zoo, originally to serve in the 'Tiere-live Show' which is conducted every day. The training was not satisfying and she was therefore placed in a normal aviary. Randall was bought as a companion. There were no breeding attempts within the last 5 years. Some of the keepers suggest that this is due to the fact that Ivan was raised by hand. She shows great interest in some of the keepers and produces sounds that can be interpreted as 'Hallo' if a person she knows approaches the aviary. Inter-individual relation between the two ravens is balanced, but Randall usually goes for the food first.

3.1.3 Striated caracaras

Female caracara: Muffin; ♀
Birthdate: May 24th 2014 in Tierpark Cottbus; lives at Zoo Heidelberg since Oct. 5th 2014 (Zoo-Heidelberg, 2015a)
Male caracara: Donut; ♂
Birthdate: between Jan. 1st 2013 and Dec. 31th 2013 in Vogelpark Irgenöd; lives at Zoo Heidelberg since Oct. 5th 2015 (Zoo-Heidelberg, 2015b)

The two caracaras are housed in two separated aviaries during the period of research. Both are new to the Zoo Heidelberg and still have to get habituated to each other. The individuals were purchased for the 'Tiere-live Show'. The aviaries are same sized and located outside of the visitor area. The aviaries outdoor area has a dimension of 3.5 m x 3.6 m x 2.4 m (12.6 m^2; 30.2 m^3) and the indoor area is 2.2 m x 3.5 m x 2.2 m (7.7 m^2; 16.9 m^3) in size. Both individuals are feed usually around 1 am and occasionally in the morning, too. They receive a diet consisting of mice, rats, chicks, and horse meat.
Muffin already receives training for the 'Tiere-live Show': before, but not during experimenting period she was trained to touch and stand on a football. She has a more curious personality than Donut and is less afraid of humans. The two birds shall be socialized for company and maybe breeding purpose in future.

3.2 Neophobia test

To check for neophobic or neophilic behaviour the birds were tested for their willingness to feed with a novel object next to their food (Biondi et al., 2010; Greenberg, 1984). This the most common approach for testing neophobia (Greenberg & Mettke-Hofmann, 2001). First a small amount of desired food (depending on the species the keepers selected appropriate food to ensure high motivation) was placed on the usual feeding site to check if the birds were willing to feed. After consumption a member of the staff placed the rest of the food in the usual place, along with the neophobia testing object (NTO). The time from introduction of the NTO until first consumption of food or first contact with the NTO was recorded, a testing session ends after such a contact occurred, or after 15 min without any contact. This test was conducted once with every bird. The keas and raven, which are housed in the same aviary were not separated for the test. Their separation could have unforeseen effects like increasing neophobic behaviour (see 5.2.2 Neophobia test).

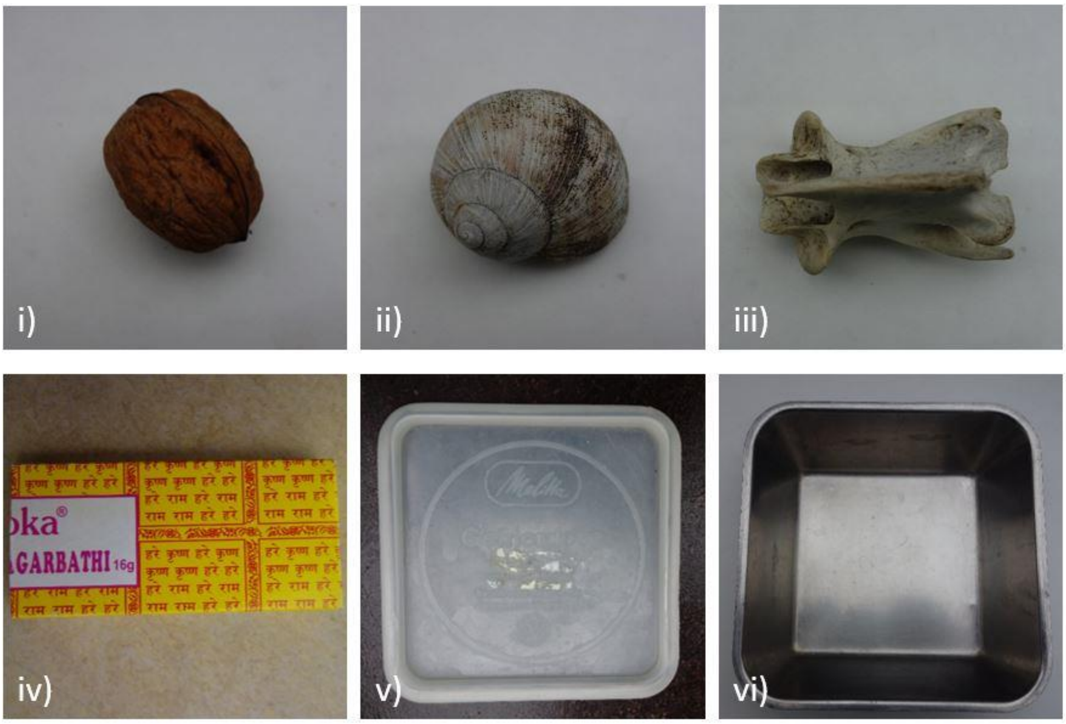
Pic. 4: Neophobia testing object (NTO); For the neophobia test he birds willingness to feed with the NTO next to their food was examined.

The novel object could be any unnatural, unfamiliar, moving object. In this case a transparent plastic bottle (21 cm x 6 cm) with a red cap. The bottle was filed up to ¼ of height with smaller stones to increase the weight, the rest of the internal volume was filed with small sparkling, golden beads (see **pic. 4**). Shiny blue and red ribbons were attached with a lace, they are light enough to move in the wind.

3.3 Object exploration test

To examine object exploration behaviour the satiated birds were presented with a set of six non-edible objects, three of them natural (a white snail shell, a spine bone of a cow and a walnut) and three of them unnatural (a semi-transparent plastic lid (12 cm x 12 cm), a small steel bowl (11 cm x 11 cm x 3 cm) and orange-red cupboard box (11 cm x 5 cm x 1.5 cm) (see **pic. 5** for the objects). The objects were placed in a pseudo-randomized order 15 cm between them. Ideally none of the objects should be seen by the individuals prior to testing. However, when the trials were already running it came to the authors knowledge, that the raven and kea sometimes receive halved walnuts. Besides from this exception the birds had not seen these objects before the experiment.

One 15 min experimental session was conducted with every individual. During the session approach latency, latency to first contact, the number and type of objects touched (either with the bill or the claws), the contact time for unnatural and natural objects and the total exploration time were measured. Exploration time is the elapsed time spend in the range of approach latency to any of the objects, including the possibility of carrying objects around and staying thereby in the range of approach latency of them. The ravens could not be separated for testing (see 5.2.3 Object exploration).



Pic. 5: Objects used for the object exploration test: **i)-iii)** natural objects; **iv)-vi)** unnatural objects; **i)** walnut **ii)** snail shell, **iii)** spinal bone of a cow, **iv)** cuppoard box (11 x 5 x 1.5 cm), **v)** plastic lid (12 x 12 cm), **vi)** steel bowl (11 x 11 x 3 cm)

3.4 Problem solving test

3.4.1 Habituation and motivation

The problem solving test is the most extensive experiment described in this thesis. It consists of 5 stages, varying in complexity. A wooden box (see **pic. 6**) containing some desired food has to be opened in each trial.

To habituate the birds with the experimental setup the box is placed in the aviary for a minimum of 48 h. From the second day on the most desired food is placed in the box. If the individuals do not go for the food within 15 min it is placed next to the box, only a small amount is left in the box. This is repeated until the testing subjects go for the food placed in the box. After the habituation is completed the box is introduced for the duration of the tests only.

Since the diet of the birds varies on daily basis the keepers, who know the feeding habits of each bird well, decide each day, which would be the most desired food. For caracaras this in general is meat (mouse, rat baby, chicken, or horse), for the keas some nuts and for the raven meat (mouse, rat baby, chicken, mealworm, fish). The birds receive their normal meal after the testing sessions are terminated.

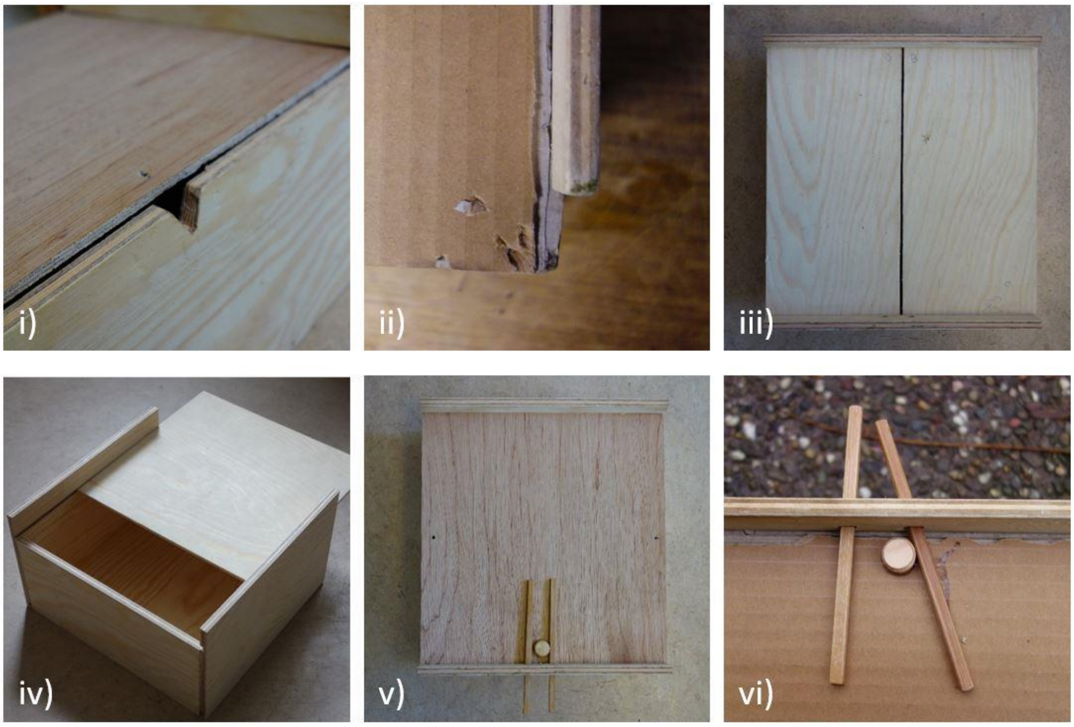
The amount of days elapsing before the birds go for the food during the habituation is also a second test for neophobic or neophilic behaviour. Unlike the NTO the box is not designed to alienate the birds, but the localisation of the food in the box is very different from the tray where the food is received normally.

Pic. 6: Wooden box used for the Problem solving test (26.5 x 25 x 12/15 cm)

3.4.2 Stages & adaptions

For all the experimental stages the open box was first introduced into the aviary. Subsequently the desired food was placed into the box, so that the birds could see it and closed afterwards according to the respective stage.

The keas could not be separated for experimental purpose, therefore in all following stages two boxes were introduced to minimise the interference between the two individuals. Similarly a change in the experimental setup had to be undertaken for the ravens: when the wooden lid was introduced to them they did not go for the box at all. Most likely this can be accounted for by their strong neophobic behaviour (Heinrich, 1988). The only solution to make them work with the experimental setup was to replace the lid by a same sized cupboard lid. Hence all the stages described below are modified in the way that the wooden lids are replaced by same-sized cupboard lids for the ravens.



Pic. 7: Details of the box for the problem solving test: **i)** the cut out notch for grapping the lid, **ii)** modification of setup 3-5 for the ravens, **iii)** setup 3, **iv)** setup 4, **v)** setup 5, **vi)** detail of setup 5

3.4.2.1 Stage 1:

The lid is placed on top of the box, but not fixed into the slider. There is visual access to the food, without touching the setup. Alternatively the lid is aligned with the two protruding edges, so that only two gaps of about 2 cm height are left on opposite sides of the box, still leaving visual access to the food. There are several ways to solve this problem: (1) the birds can reach down to the food with the bill, without handling the lid on purpose; (2) using the bill or claws to push or pull the lid away and (3) turning the box upside down or tilting it.

3.4.2.2 Stage 2:

The lid is placed on the box, as described in the setup for stage 1 but now the lid is weighted down by a stone, which has approximately ½ of the bird's weight (tree flat stones with weights between 591 and 791 g were in use). There is still visual access to the food. This setups can be solved by lifting up the lid a bit, so that the stone glides down or by lifting up the whole box. Pushing the lid away does not work with every lid position, the lid can fall into the box in a way, that it is pressed down by the stone and thereby blocks the access to the food or make it much harder to obtain access.

3.4.2.3 Stage 3:

In this stage the lid consisted of a two part gliding lid, as described by (Fritz & Kotrschal, 1999) but the use of outwardly showing flaps for pulling was altered and eventually abandoned (see **tab. 2** for details of affected individuals and stages). Starting from stage 3 the boxes had a small notch (**pic. 7 i)** shows this detail) which allowed the bird to grab the lid without any extension. The ravens setup was modified since no cord could be attached to the cupboard lid. Instead the cupboard lid was protruding 0.5 cm over the side the box and was therefore easy to grab (see **pic.7 ii)**), this adaption was used for all stages.
There was no more visual access to the food (as in all the following setups) after the lid is closed (see **pic. 7 iii)**). The setup can be solved by pulling on the lid, pushing both lids away in one direction, or sliding them apart while performing a movement which is aiming directly at the food.

3.4.2.4 Stage 4:

Instead of the two part gliding lid (stage 3) an on-part gliding lid was slid into the box (see **pic. 7 iv)).** Everything else was conducted, as described in stage 3. This setup can be solved only by pulling or pushing. The lid will not fall out from twisting the box or pulling it over. It is also not possible to perform a movement, which is aiming at the food directly to obtain the food, and thereby unwittingly pushing the two lids apart, as in stage 3.

3.4.2.5 Stage 5:

The setup was equal to setup 4. But the lid was now blocked from pulling out by two bolds (see **pic. 7 v)** and **7 vi)** for a close up). For Muffin (the female caracara) bolds with a length of 4 cm were used, in all following experimental sessions this setup was modified slightly: the original bolds were replaced with bolds that had the same diameter but were 12 cm in length, to prevent the birds from swallowing these small parts. At least one of the bolds must be pulled out, or must be removed in another way e.g. turning the box upside down in the right direction (see **pic. 9 iv) – vi)**) in order to obtain the food.

3.4.3 Measured parameters

The following data was recorded in each of the 5 stages (a) approach latency A: the elapsed time from the beginning of the experiment to the time, when the individual approached the box within a range of 10 cm, (b) contact latency B: the elapsed time from first approach to first contact with the bill or claw, (c) the number of contacts: any contact with either the bill or the claws, a contact was regarded as finished after 5 sec without contact to the box, (d) consumption latency C: the elapsed time from first contact to consumption of the food placed in the box and (e) total exploration time: elapsed time from first approach until consumption. The measured latencies are clarified in **fig. 1**. The measured latencies are oriented on the work of (Biondi et al., 2010).

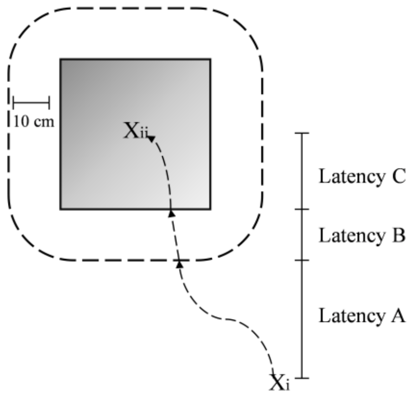


Fig. 1: Visualisation of the measured latencies during the problem solving experiment; the dashed arrows resemble a birds potential path; **Latency A**: Elapsed time from the start (Xi) of the experiment (as soon, as the keeper has left the 10 cm range surrounding the box) to the time, when the bird oversteps the 10 cm radius surrounding the box (dashed square); **Latency B**: Elapsed time from overstepping the 10 cm radius to first contact with the box (grey shaded square); **Latency C**: Elapsed time from first contact with the box to consumption of the food in the box (Xii)

3.4.4 Testing schedule

For stage 1 three sessions á five trials were conducted. However, this proofed to be inflexible, since some birds gathered 15 successful trials, whereas others gathered below five within three sessions. It was therefore decided to rearrange the testing schedule from stage two on as follows: Each stage consisted of a minimum of six successful trials. Consecutive sessions with the same stage were conducted until a minimum of six successful trials was recorded. The setup of each respective phase was considered as failed and not repeated further with the individual, in case six successful trials could not be recorded within five testing days or if the individual showed clearly neophobic behaviour.

Success was defined as taking food out of the box after opening it, performed by the same individual without help from another bird or keeper. If the birds lost interest in the experimental setup and had no contact with the box for more than 5 min or did not consume the food in the box within 5 min after opening it the experimental session ended and was counted as failed.

The tests were performed around the same time of day for the individuals of each species, always before feeding. Since the feeding times differ between species the raven were tested in the morning, the caracaras shortly after noon and the keas in the early afternoon (for exact times see the feeding schedules in 3.1 Subjects).

3.4.5 Methodical modifications of the testing setups

The setups of the experiments had to be adapted due to unforeseen conditions sometimes. **Tab. 2** is a complete list of the adaptions (apart from these ones already mentioned above) during the problem solving experiments work along with short explanation of their causing. These modifications and their potential impact on the results are discussed in detail in 5.2.4 Problem solving.

Modifications of the problem solving setup

Modification	Impacted experiments and individuals	Explanation
Duct tape flaps for pulling	Stage 3 of the problem solving test for both caracaras; first session of stage 4 for Muffin	Muffin started chewing of parts of the tape. The setup had to be modified for subsequent experiments, to minimize the risk of swallowing small plastic part and a cord was introduced.
Replacing the flaps with cords for pulling	Stage 4 for Donut, and 2nd session of stage 4 for Muffin	The birds started chewing of parts of the cord. The setup had to be modified for subsequent experiments, to minimize the risk of swallowing small parts of the fiber: no extensions for pulling the lid
No extensions for pulling	Stage 3 to 5 for keas and raven; Stage 5 for the caracaras	The use of a flap for pulling was rejected. Since testing periods were asynchronous keas and raven had altered experimental setups from the beginning of stage 3.
Cupboard lid	Stage 1 to 5 for the raven	The raven showed very neophobic behaviour towards the wooden lid. So it was replaced with a same sized cupboard lid in all experiments. The experimental setup itself was not affected in any way.
Two boxes	Stage 2 to 5 for the keas	It was not possible to separate the two birds for these experiments, but there was also a lot interference between them. The solution was to introduce two boxes at a time, which minimized suppression of the subdominant individual. (see **pic. 9 i) – iii))**

Tab. 2: List of modification within the setup of the problem solving experiment; including the impacted stage and individuals, the modification and a short description of the causative reasons

3.5 Video recording & data processing

The videos were recorded using a Sony "Cyber-shot DSC-RX 100" camera on a tripod. The camera was located outside the aviary, always at the same location. Filming started during the habituation phase to habituate the birds to the camera and the experimenter's presence, too. The latencies were measured using a stopwatch and the "VLC-media player". The videos were indexed with a distinct number, along with date, distinct description of the experiment, the participating individuals, the duration and comments (if necessary) in Excel. During recording the videos of the experiments specific events as e.g.

‘start’, ‘contact (with object-x)’ or ‘consumption’ were spoken, in case video material was ambiguous. These comments were used to determine time-marks.

The data were processed with Excel. For each Individual an Excel-sheet was arranged. For an example sheet of the problem solving test see **pic. 11** in the appendix. These tables contained all the measured parameters plus additional information like video-ID and comments The data of the problem solving experiments of all six birds were compiled into one raw-data table. This table was converted into a Power-Pivot table (see **pic. 12** in the appendix) for easy handling.

For the Object exploration test an Excel-sheet was arranged for each individual containing the measured parameters (see 3.4.3 Measured parameters) and additional information (see **pic. 13**in the appendix).

3.6 Data analysis

Statistica 12 (STATISTICA Desktop version 12.70 for Windows, StatSoft, Hamburg, Germany, www.statsoft.de) and GraphPad Prism 5 (GraphPad Prism version 5.00 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com) were used for statistical analysis. The figures were produced with GraphPad Prism 5, too.

For the neophobia test and the object exploration test the mean and SE was calculated using GraphPad Prism 6 (GraphPad Prism version 6.00 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com). No further statistical analysis was applied for these tests, since two measurements per species are not enough, for obtaining statistically relevant results. The problem solving experiments underwent several tests: an one-factorial Friedman-ANOVA was performed to test, if significant differences between the stages 1 – 5 exist in latency C (see 3.4.3 Measured parameters) therefore the mean of latency C was calculated for every species. The aim of this test is, to find out, if significant differences exist in the duration, necessary to solve the different stages, since this could give a hint about differences in difficulty. For this test the independent variable was stage, and the dependent variable was species. The one-factorial Friedman-ANOVA was also used to check for significant differences in latency A, B, C and the number of contacts between species. To check for differences between species the mean of the cumulated measurements (A, B, etc.) was calculated per species and stage. In this case the independent variable was species and the dependent variable was stage. All Friedman-ANOVAS were followed by Dunn’s multiple comparison test.

4 RESULTS

4.1 Neophobia test

4.1.1 Neophobia test

The Results for the neophobia test, where the elapsed time from introducing the neophobia testing object (NTO) until contact with the food or the NTO was measured, are displayed in **fig. 2** for all six participating individuals. The mean of the species is given in **fig. 3**. The maximum duration is the maximum testing time, afterwards the test was counted as failed.

Both ravens failed the test. The NTO was removed from their aviary after 17 min. But filming was continued until 23 min after introducing the NTO out of curiosity. Not even than they had touched the food, which had been laying close to the NTO. The two caracaras both succeeded after different times and the keas both succeeded within 1 sec after start of the test, although Maggie, the female, had no contact with the NTO: Already before the experiment had started they both seated themselves next to the transparent sliding door and Crusty immediately touched the NTO before taking interest into the food which had been introduced simultaneously. Maggie, moved towards the NTO and was in close range to it (below 10 cm), but Crusty prevented the contact and chased here off after here attempt. The NTO had to be removed soon after, since he started chewing on the ribbons. Therefore the best presumption which can be made is to adopt the measurement from Crusty for Maggie. To say she is behaving very neophobic towards the NTO instead and count the test as failed would be a clearly wrong assumption which disregards, that two individuals participate in the test simultaneously. Also it would contradict the contemporary state of research about keas (Keller, 1975).

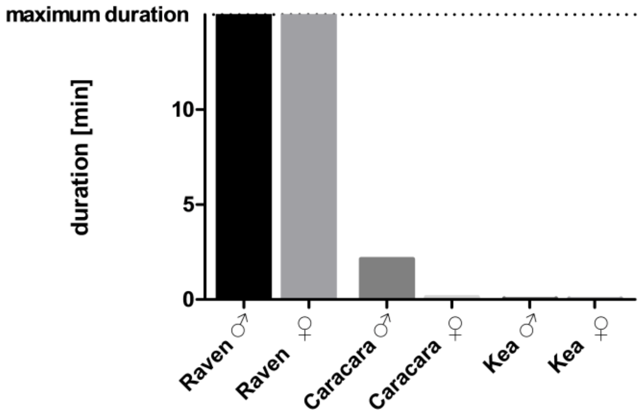


Fig. 2: Neophobia: Latencies for the time to consumption during the neophobia test; the dotted line marking the maximum duration of the test does not indicate the time of consumption, but the time of termination of the test; the measured values are given in **tab. 3** in the Appendix

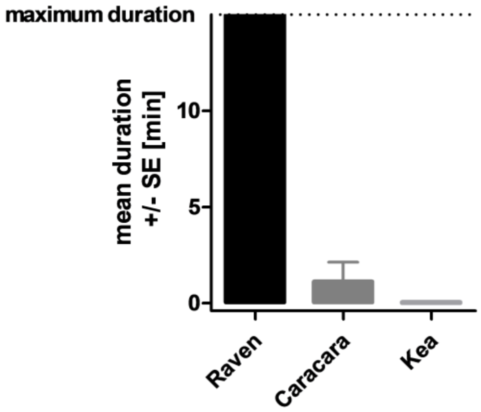


Fig. 3: Neophobia, mean of species: Mean of species for latencies to consumption during the neophobia test; the dotted line marking the maximum duration of the test does not indicate the time of consumption, but the time of termination of the test; the measured values are given in **tab. 3** in the Appendix

4.1.2 Habituation for the Problem solving test

As described in 3.4.1 Habituation and motivation the habituation phases of the problem solving test also served as a test for neophobic and neophilic behaviour. Unlike the NTO (see **pic. 4**) the box (see **pic. 6**) is not designed to scare the birds but the position of the food in the box differs from the habitual feeding site. The following observations were not made quantitative, but qualitative aiming to describing the behaviour of the birds.

4.1.2.1 Ravens*:*

The habituation for the raven took the longest: seven days. When the box was introduced, they neither showed apparent fear nor interest. No contact was made during personal observation and during staff observation. The box remained in its place and was not dragged around. On the fifth day meat was introduced on the edge and in the box. The rest of the food was placed in the usual feeding place of the birds. Normally the ravens choose the meat first, but this day some usually undesired food was taken from the tray instead of the box. After 5 to 10 min Randall, the male, took the first piece of meat from the box, and soon after the second piece. In the following two days Randall approached the box within 18 to 25 sec and took out the food successively. He never showed any of the exited or leery behaviour which could be observed in Donut's (caracara) trials. But contact was not made more than necessary. Ivan did not approach the box at all during habituation and showed no interest in it even when food was presented in the box. However, she always profited from the food which Randall had retrieved.

4.1.2.2 Keas*:*

Habituation for the keas was shortest and needed only the minimum duration of two days: when the box was introduced without food on the first day they made contact with it after 5 sec without hesitation. The box was dragged around, turned upside down and looked at from all sides, they sat on it and tried to pick it. This period of focused interest and handling was short and they left it to feed. But they came back every minute for a couple of seconds to investigate the box again for the next 8 minutes and with more extended gaps afterwards. In the second day of habituation the birds had lost any interest into the box before the food was provided in it, it swam in the small pond of the aviary. The box was taken out of the pond and food was introduced. Crusty immediately approached the box (below 5 sec) and started feeding. Maggie could only sneak out some food occasionally, because Crusty tried to prevent here from obtaining food from the box.

4.1.2.3 Caracaras:

The habituation for the caracaras differed between the two individuals in duration: for Donut, the male, three days were necessary, for Muffin the minimum duration of two days. When the box was introduced first to Donut he showed great interest. Picking, touching shortly with the foot and rebounding rapidly could be observed within the first 5 min, the interest decreased over time. When the box was introduced the next day with food Donut showed great interest and apparently little fear, he behaved very leery and suspicious, jumping and mincing around the box, walking around in circles. He fetched the first of two mice after ca. 4 min. When he had eaten the first mouse he fetched the second after walking around the box again and flew away very fast thereby crashing into the box. It was therefore decided to add a third day for habituation. On the third day Donut showed similar behaviour to the day before, but took out the food after 1:30 min only.

Muffin, the female, showed some interest into the box but no fear at all. The period of inspection was short. On the second day, when the food was introduced in the box she went straight for the food within 4 sec after the keeper had left the aviary. Muffin took the food without displaying any of the behaviour, which had been observed for Donut. No attention was payed to the box afterwards.

4.2 Object exploration test

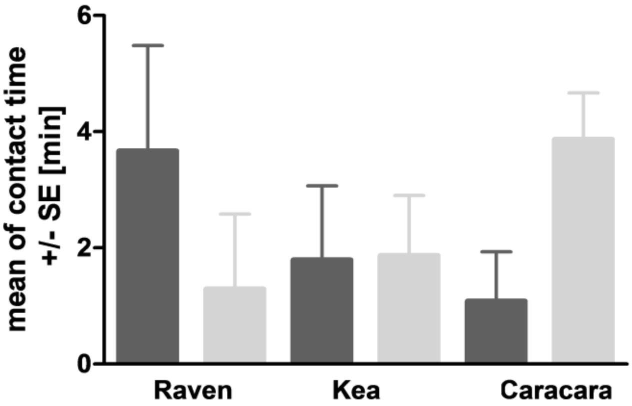


Fig. 4: Object Exploration, mean of contact time: Mean of cumulated contact time for objects in the category ‘natural’ and ‘unnatural’ for each species; the underlying measurements are displayed in **tab. 4** in the Appendix

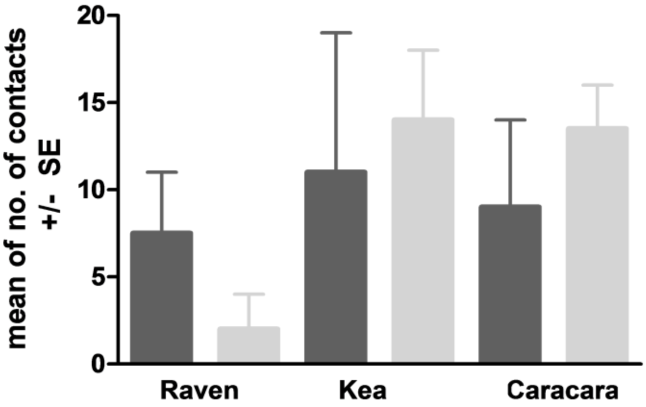


Fig. 5: Object Exploration, mean of contacts: Mean of the cumulated number of contacts for objects in the category ‘natural’ and ‘unnatural’ for each species; the underlying measurements are displayed in **tab. 5** in the Appendix

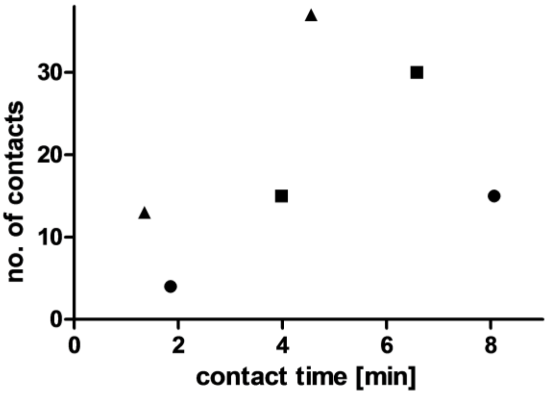
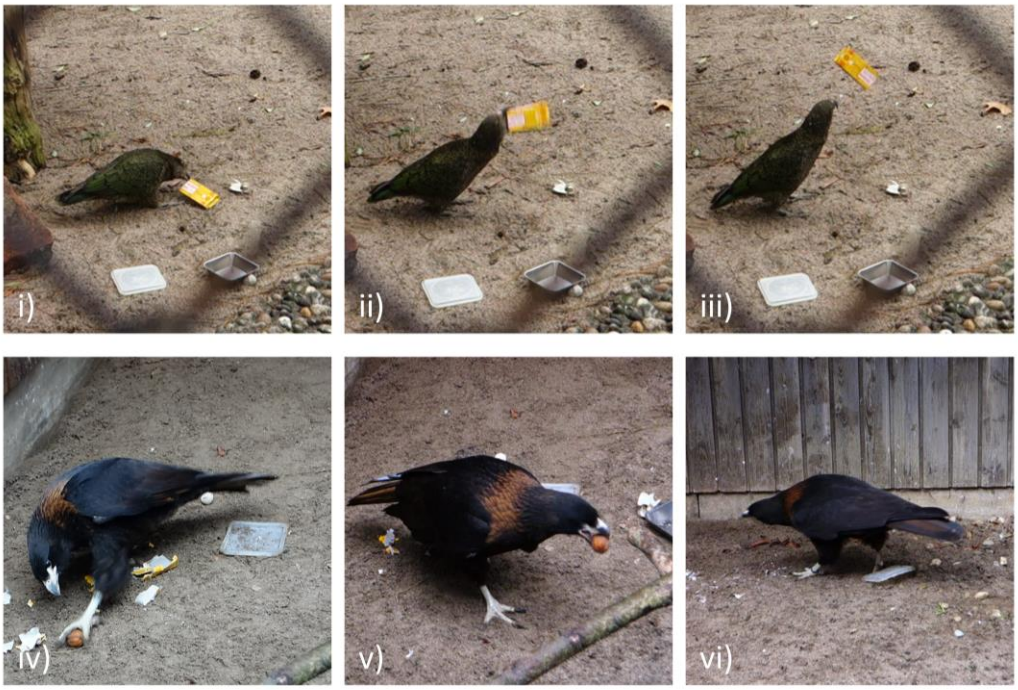


Fig. 6: Object Exploration, number of contacts and contact time: each point represents one individual; see **tab. 4** and **tab. 5** in the appendix for values



Pic. 8: Typical behaviour during the object exploration test for keas and caracaras; **i)** - **iii)** Crusty, the male kea looking into the yellow cupboard box and throwing it into the air afterwards, throwing objects was repeated with several objects; **iv)** Maggie, the female caracara first touching the walnut and looking at it; **v)** Maggie carries the walnut away to investigate it somewhere else; **vi)** Maggie carries the plastic lid with her food

During the object exploration test all individuals made several contacts with the presented object (ranging from 4 to 37 contacts) for 1:51 min to 8:04 min. The ravens showed a preference for natural objects and the caracaras showed a preference for unnatural objects. The keas showed no noticeable preference. Between the ravens the biggest difference in contact time could be observed and between the keas the biggest difference in number of contacts (see **fig. 6**).

4.2.1.1 Ravens:

Unlike the other birds the raven were tested simultaneously in the same aviary (see 5.2.4 Problem solving for discussion). Apart from one indirect interaction between the birds, i.e. Randall, the male, excavated the walnut, which Ivan had cached and left in the sand before, no further interactions occurred. Randall had contact with two of the natural objects (walnut, snail shell) and one of the unnatural objects (yellow cupboard box). Ivan had contact with one of the natural objects (walnut) and none of the unnatural objects (see **tab. 5** in the Appendix). Contacts were made in short intervals, seldom with a duration above one minute during the whole testing session. Usually one contact was made followed by a short drawback before making contact with the next or the same object again. The Yellow cupboard box was teared into smaller parts by Randall and both birds carried the walnut around the aviary. No other objects were displaced. The ravens average contact duration for natural objects was 3:40 min and 1:18 min for unnatural objects (see **tab. 4** in the Appendix), the average total contact time was 4:58 min. The total exploration time (see 3.4.3 Measured parameters for description) was comparably high for both ravens but differed remarkably: 10:01 min for Randall and 2:43 for Ivan.

4.2.1.2 Keas:

Crusty, the male kea touched every single object once with the bill and tongue in the beginning of the testing session, before turning his attention for longer periods to single objects. Maggie probed every single object, too, but in a more random order. **Pic. 8** displays generic behaviour during the Object exploration test for keas and caracaras. In **pic. 8 i)** – **iii)** Crusty can be seen whilst looking into the yellow cupboard box and flipping it into the air afterwards. This was repeated twice. Subsequently he repeated this procedure with the steel bowl. It generated a relative loud noise, especially, when the bowl was falling on stony ground. He repeated this behaviour for four times on the stones, until the bowl fell into the small pond. Crusty relocated the walnut, the steel bowl and the plastic lid into other areas of the aviary. Maggie replaced none of the objects. Investigating the objects occurred in three intervals: bot keas lost interest into the objects for two times, but came back to investigate them again after intermissions ranging from one to six minutes. The average contact duration was 1:48 min for natural and 1:52 min for unnatural objects, the average total contact time was 3:40 min. The total exploration time for Crusty was 1:47 min and 6:50 for Maggie

4.2.1.3 Caracaras:

Muffin, the female caracara had contact with all six objects, Donut had contact with all object except for the walnut. Handling behaviour normally was a combination of holding an object with the food and probing it with the bill at the same time. **Pic. 8 iv)** – **v)** shows Muffin probing a Walnut with the food and carrying it to a different location for investigation. The objects often were carried somewhere else, flying or walking (see **pic. 8 iv)**) for an example of Maggie carrying around the plastic lid), to an elevated point for probing it. Both caracaras teared the yellow cupboard box apart completely. The contact behaviour of Donut was similar, to that of the ravens: Contacts were made in short intervals, seldom with a duration above 30 sec during the whole testing session. Usually one contact was made followed by a short drawback before making contact with the next or the same object again. He lost interest into the objects once for four minutes but came back once more for two min. Muffin's contact behaviour was more similar to the keas: she investigated the objects in five intervals with intermissions of 1:30 min to 4 min between them. The average contact duration was 3:40 min for natural and 1:18 min for unnatural objects, the average total contact time was 4:57. The Total exploration time for Randall was 10:01 min and 2:43 min for Ivan.

4.3 Problem solving test

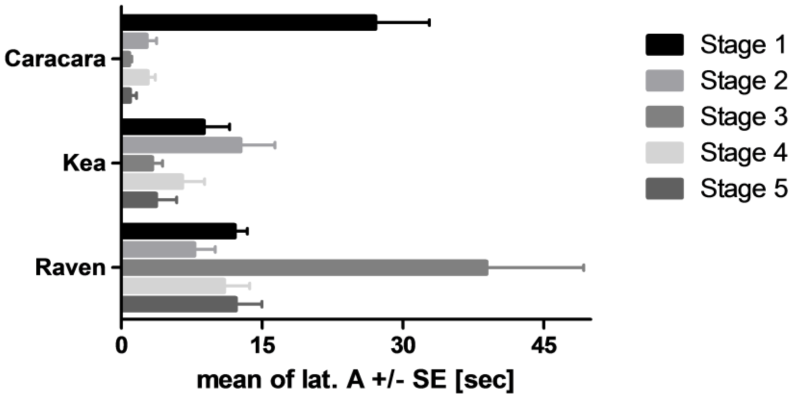


Fig. 7: Problem solving, mean of approach latencies (A) pooled for species: the mean was calculated with the pooled data of all successful trials; for the underlying data see **tab. 6** – **8** in the appendix; for the ravens stage 1, 3 and 5 consists of data from the male only, since the female did not participate in the test for unknown reasons

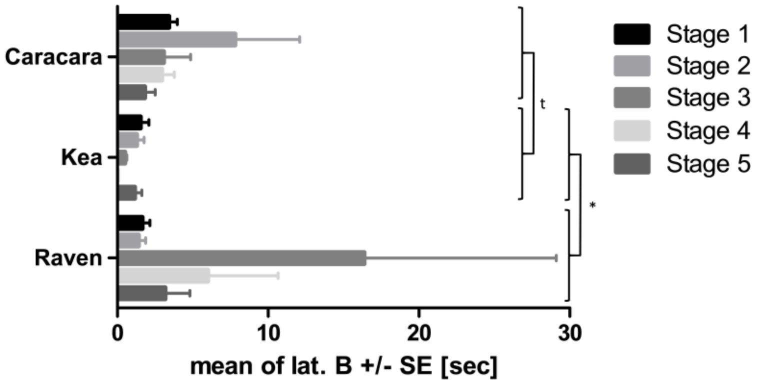


Fig. 8: Problem solving, mean of contact latencies (B) pooled for species: the mean was calculated with the pooled data of all successful trials; for the underlying data see **tab. 6** – **8** in the appendix; for the ravens stage 1, 3 and 5 consists of data from the male only, since the female did not participate in the test for unknown reasons; t indicates a tendency (p < .100)

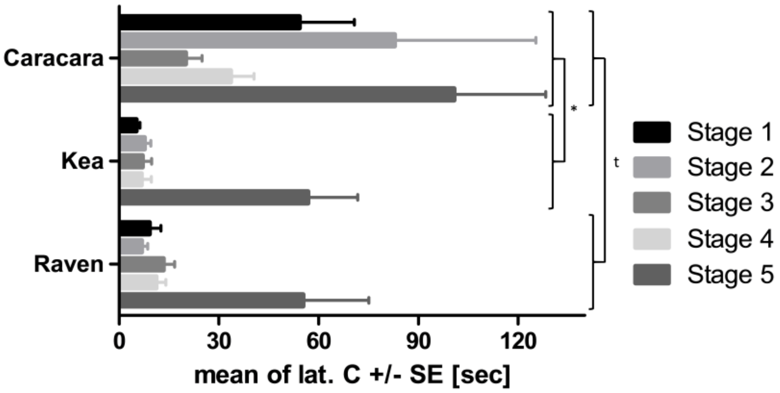


Fig. 9: Problem solving, mean of consumption latencies (C) pooled for species: the mean was calculated with the pooled data of all successful trials; for the underlying data see **tab. 6** – **8** in the appendix; for the ravens stage 1, 3 and 5 consists of data from the male only, since the female did not participate in the test for unknown reasons; t indicates a tendency (p < .100)

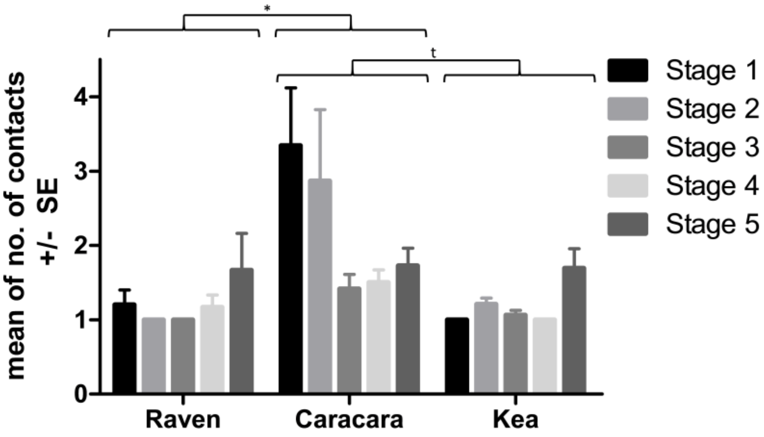
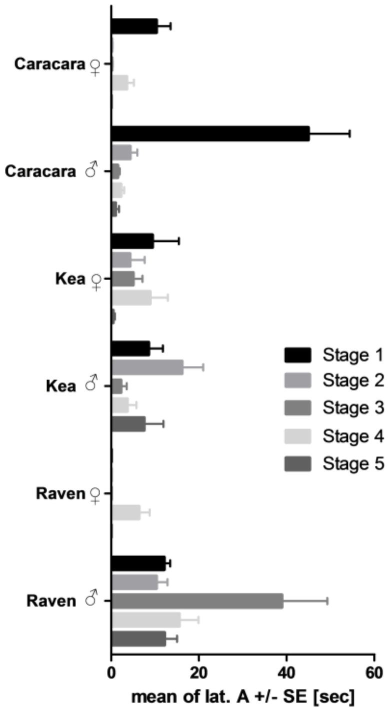
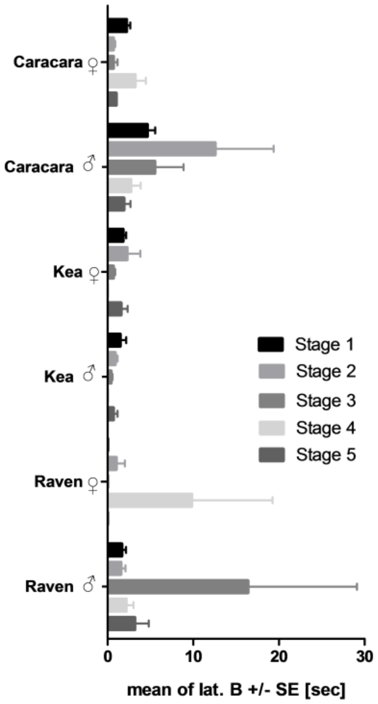


Fig. 10: Problem solving, mean of number of contacts pooled for species: the mean was calculated with the pooled data of all successful trials; for the underlying data see **tab. 6** – **8** in the appendix; for the ravens stage 1, 3 and 5 consists of data from the male only, since the female did not participate in the test for unknown reasons; indicates a tendency (p < .100)





(left) **Fig. 11**: Problem solving, mean of approach latencies (A): mean of latencies A for each of the six individuals; for the underlying data see **tab. 6** – **8** in the appendix; for the female raven no data exist for stage 1, 3 and 5 since she did not participate in the tests for unknown reasons

(right) **Fig. 12**: Problem solving, mean of contact latencies (B): mean for each of the six individuals; for the underlying data see **tab. 6** – **8** in the appendix; for the female raven no data exist for stage 1, 3 and 5 since she did not participate in the tests for unknown reasons

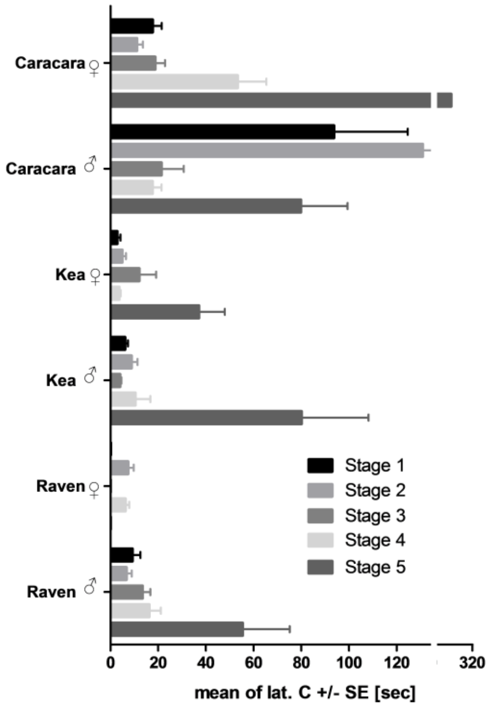


Fig. 13: Problem solving, mean of consumption latencies (C): mean for each of the six individuals; for the underlying data see **tab. 6** – **8** in the appendix; for the female raven no data exist for stage 1, 3 and 5 since she did not participate in the tests for unknown reasons

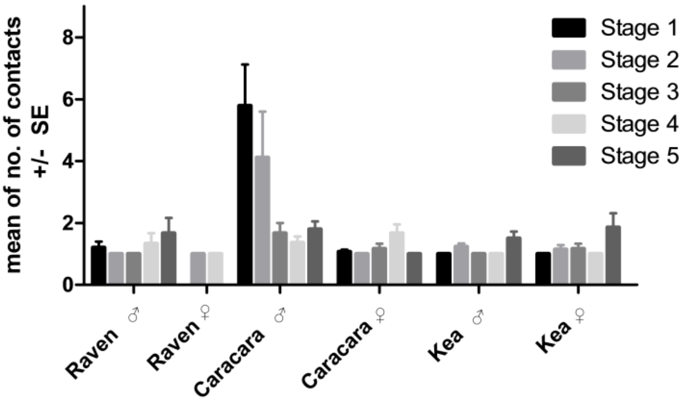
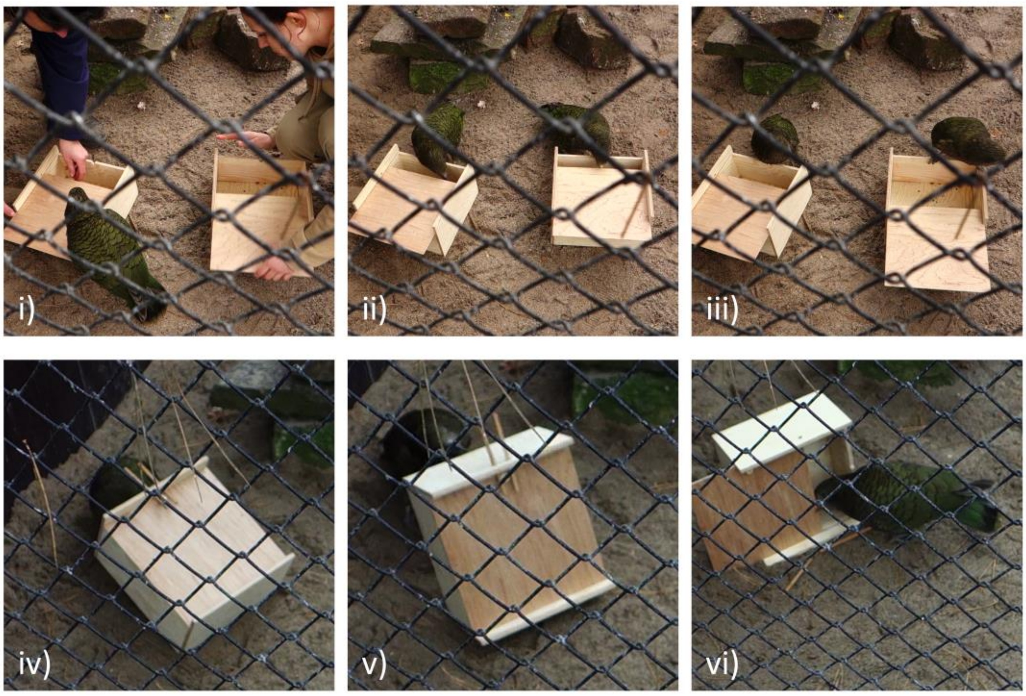
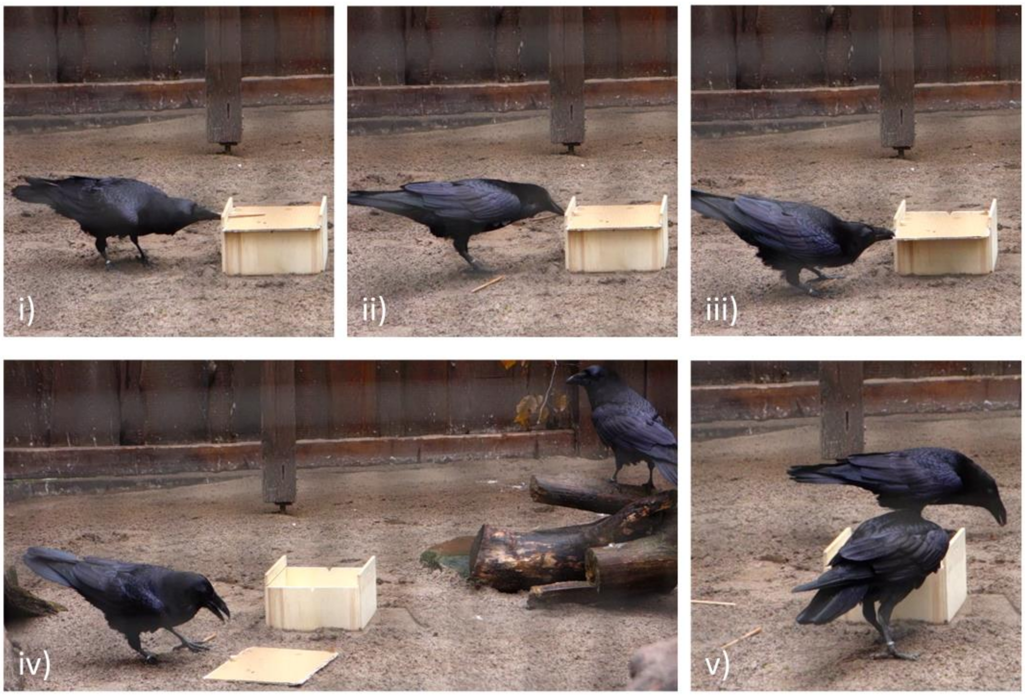


Fig. 14: Problem solving, mean of number of contacts: mean for each of the six individuals; for the underlying data see **tab. 6** – **8** in the appendix; for the female raven no data exist for stage 1, 3 and 5 since she did not participate in the tests for unknown reasons



Pic. 9: **i) - iii)**: Demonstration of the two box adaption of the problem solving experiment for the Keas: **i)** each box is filled with food by a keeper and they are closed concurrently (sometimes one of the individuals was approaching the box before the start of the measuring which leads to an approach latency A of 0 sec); **ii**) the individuals approach a box each; **iii)** both individuals have obtained food from a box; **iv)** Crusty is performing an alternative approach to solve stage 5: setting the box on one side; **v)** the bolds do fall out sometimes which enables him to; **vi)** slide the box open to get the food



Pic. 10: Problem solving stage 5: typical behaviour of problem solving and interaction between Randall and Ivan; **i)** and **ii)** Randall pulls out the two bolds one after the other; **iii)** Randall slides out the lid; **iv)** the lid is slid out of the box, Ivan can be seen sitting close to the box following his action; **v)** both birds feed on the food in the box

4.3.1.1 Ravens*:*

For the ravens the average duration of latency A (the time to first approach (see **fig. 1**)) across all stages is nearly 10 sec longer than for the other two species with an average duration of 16.4 sec. Also the average duration of latency B (time to first contact) across all stages is longest with 5.7 sec. However, the average duration for latency C (time to consumption from first contact on) across all stages is with 19.2 sec similar to the time of the keas. The number of contacts is also equal to the keas: 1.2. The average duration of latency B is close to that of the other two species for stage 1 and 2 but their measures increased above all the other species in stage 3, slowly decreasing in subsequent stages (see **fig. 8**). In stage 3 they hesitated for 16 sec in average, which is the highest measure for all stages and species. The average duration of latency B increased by 15 sec between stage 2 and stage 3. Stage 3 was the first experimental setup, where food was not visible any more. On the first day, when this setup was introduced they both did not approach the box and did not even land on the ground. In the third trial of stage 3 Randal came 0.5 m close to the box but behaved very suspicious. He ploughed his bill through the sand of the aviary (this is a movement, which the birds normally perform on stones or branches) and jumped backwards. He never came in the 10 cm range of the box during this first day.

There was little interference between the ravens and the test with one box proofed to be suitable. Ivan, the female raven, rarely conducted a trial: only on two research days out of 15. On the other days she occasionally approached the box, but generally only after Randal had opened it already. Either to get some food out of the box or to probe the lid with the bill (see **pic. 10**). There was no hindrance for Randal to solve the setup. When Ivan approached the box this happened generally only after Randal had made contact to the box already.

4.3.1.2 Keas:

The average duration of latency A across all stages is the same as for the caracaras: 7 sec. The average duration of latency B across all stages is with 0.9 sec the shortest of all three species. But for the keas there was strong suppression of the subdominant female by the male. These two latencies would probably be very different, if the birds were tested individually. It proofed to be a simple but effective solution to use two boxes (see **pic. 9 i) – iii)** for a series displaying the two individuals solving their box each) but also increased the number of people involved in the setup to three (two keepers filling and closing the boxes concurrently, and the author of this thesis filming and taking notes). It still happened that one individual solved its box faster and went to the second box immediately, thus disrupting the other individual, or went there straight without solving the box intended for it first. Since only successful trials were used for statistical analysis the measurements of latency C are unaffected by interference (otherwise the trial would not have been counted). The keas outperformed both other species in the average duration of latency C across all stages with a duration of 16.7 sec. There is a clear tendency for stage 5 needing much more time (see **fig. 9**). There are little differences between the two individuals (see **fig. 13**) but Maggie, the female, had the shortest average duration for solving stage 5 of all individuals tested (37 sec).

4.3.1.3 Caracaras:

For the two caracaras partly large differences exist between the individuals. Their average duration of latency A across all stages is 6.9 sec (same as for the keas) despite the fact that Donut, the male, needed much longer than Muffin. Donuts average approach latency of stage 1 is longer (44.9 sec) than that of any other individual across all stages. But after stage 1 the average duration of latency A drops (see **fig. 7**) to a level lower than that of the two other species and no big differences exist between the species (see **fig. 11**). Muffin approached the box nearly immediately after it was introduced, with an average approach latency below 1 sec in stage 2, 3 and 5 (see **tab. 7**). With 3.8 sec average duration of latency B across all stages the caracaras range in between the ravens and the keas. But again, there are large differences between the two individuals (see **fig. 12**), with Donut needing much longer. The average number of contacts across all stages is 2.2 and much larger than that of both other species (see **fig. 10**). This can be explained by Donut's behaviour: for stage 1 and 2 he needed 5.8 respectively 4.1 contacts in average (see **fig. 14**). After the first two stages the number drops, but stays at a higher level than for the other birds. Surprisingly for stage 5 his average contact number is even lower than that of the male kea. Also for the average of latency C across all stages the picture is very different for Donut and Muffin. There is a clear tendency for Muffin needing longer in the later stages than in the beginning. She was able to solve stage 5 only once and most likely by chance (see 5.2.4 Problem solving). Donut needed longer for stage 1 and 2 than he needed for stage 5. For every other individual the mean of latency C (time to consumption) was longest in stage 5.

4.3.2 Results of the statistical analysis

The statistical analysis revealed several significant effects (p<.050) and tendencies (p<.100). However, no significant differences exist between the latency C (time to consumption) in stage 1 to 5 (Friedman-ANOVA $F(5, 3) = 6.667$, $p = .1626$) (see **fig. 15**). Also no significant differences were revealed between the three species for latency A (approach latency) (Friedman-ANOVA $F(3, 5) = 3.600$, $p = .1821$). But a main effect of species on the duration of latency B (contact latency) was detected (Friedman-ANOVA $F(3, 5) = 7.600$, $p = .0239$). Post-hoc analysis with Dunns multiple comparison test specified that keas contacted the box significantly faster than ravens, and tended to be faster than the caracaras. Similarly a main effect of species on the duration of latency C was detected (Friedman-ANOVA $F(3, 5) = 7.600$, $p = .0239$). Post-hoc analysis with Dunns multiple comparison test specified that the keas were significant faster than the caracaras in opening the boxes, and the ravens showed a tendency to be faster than the caracaras. There was also a main effect for species concerning the number of contacts during problem solving (Friedman-ANOVA $F(3, 5) = 7.600$, $p = .0239$). Post-hoc analysis with Dunns multiple comparison test revealed that the ravens made significantly less contacts per trial than the caracaras, and the keas tended to make less contacts than the caracaras.

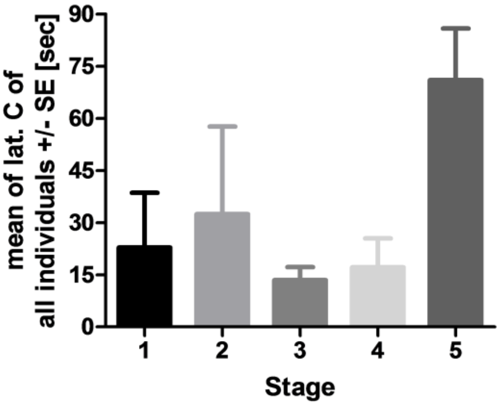


Fig. 15: Problem solving, mean of consumption latencies (C) pooled for stage: the mean was calculated with the pooled data of all successful trials of all participating birds; for the underlying data see **tab. 6** – **8** in the appendix

5 DISCUSSION

5.1 Discussion of the Results

Before interpreting any of the results it has to be made clear, that no external validity can be achieved from a sample size of two birds per species. It would be incorrect to generalize any of the conclusions below for species level. Hence the discussion of the results focuses on the comparison between the individuals housed in Heidelberg Zoo without indicating this again in the following chapter.

5.1.1 Neophobia test

The results of the neophobia test (see **fig. 3**), indicated that:

- Ravens showed very strong neophobic behaviour
- Caracaras showed very little neophobic behaviour and displayed neophilic behaviour
- Keas showed no neophobic behaviour and displayed neophilic behaviour

These results match those already known for ravens (Heinrich, 1988) and keas (Keller, 1975) from literature. For the striated caracara (*P. australis*) no literature about neophobia tests is available, however it has been reported that wild living individuals are very tame (Catry et al., 2008),which gives a hint for possibly low level of neophobic behaviour. Also island animals have smaller predation pressure (Blázquez, Rodríguez-Estrella, & Delibes, 1997; Daugherty, Gibbs, & Hitchmough, 1993) and are less neophobic in general. The caracaras housed in Heidelberg Zoo showed very little neophobic behaviour, but differences existed between the individuals (see **fig. 2**): Donut, the male approached the food very fast after investigating the Neophobia testing object (NTO) from distance, and retreated immediately after he had taken the mouse. Muffin, the female, approached the NTO directly after introduction and made contact with the NTO first, before showing interest into the food, just as the keas. She dropped the mouse and went back to investigate the NTO again. This indicates that keas and caracaras have a relative high level of neophilia, in contrast to ravens.

Two more observations, which make it clear that ravens have a very high level of neophobia are that the ravens needed much longer for habituation during the problem solving test than the keas and caracaras (see 4.1.2 Habituation for the Problem solving test). Furthermore, when the habituation was successfully terminated, they stopped to contact the box, after the lid was introduced in stage 1. The only solution to get them working with the box was to substitute the wooden lid with a cupboard lid (see **tab. 2**). Despite the fact that Randall, the male, made contact with the box from the 5th day on, Ivan never touched the box during habituation, and rarely during experimental sessions.

5.1.2 Object exploration

The object exploration test revealed some interesting differences between the three species tested. The most prominent findings are:

- Total contact time was similar between species, but lowest in keas
- Total number of contacts was similar for keas and caracaras, but lower for ravens
- Caracaras showed preference for unnatural objects, ravens for natural objects, for keas no preference was evident

Despite the fact that the neophobia test showed a high level of neophobia in ravens, the contact time was similar between all three species in the object exploration test. This displays the often neglected difference between neophobia and neophilia. These two traits are different axes of personality, rather than diametrical opposites (see 1.2 Neophobia & Object exploration).

Whilst the average total contact time (3:40 min (keas), 4:57 min (caracaras) and 4:58 min (ravens)) was similar between species (see **tab. 4** in the appendix), the ratio for contact time between unnatural and natural objects varied greatly (see **fig. 4)**: The keas had a balanced ratio with touching unnatural objects 1.04 times longer than natural objects. The caracaras touched unnatural objects 3.57 times longer, than natural objects and the ravens touched unnatural objects 0.35 times shorter than natural objects (natural objects 2.82 times longer, than unnatural objects). For the number of contacts (see **tab. 5** in the appendix) these ratios are not equal, still the tendency is the same (see **fig. 5**): the keas touched 1.27 times more unnatural objects, as natural objects, the caracaras 1.5 times more and the ravens 0.27 times less (= 3.75 times more natural objects as unnatural objects touched). But there are great differences in the total amount of contacts between the species: Keas (25 contacts) and caracaras (22.5 contacts) were similar, but ravens (9.5 contacts) had contact with less objects. Thus the species with the longest exploration time has the smallest number of contacts and vice versa.

All the birds showed distinct exploration behaviour. Their exploration behaviour was similar in duration, but differed in the number of contacts, and preference for natural and unnatural objects. This again illustrates the difference between neophilia and neophobia. The findings for ravens correspond with literature (Heinrich, 1995b; Stöwe et al., 2006). Most striking is the strong preference for natural objects in ravens and unnatural objects in caracaras. This surprising find is probably not by mere chance, since it has been shown for pigeons that they are able to use 'class-distinguishing stimulus aspects for generalization to new instances' (Huber, roje, Loidolt, Aust, & Grass, 2000), meaning that they are able to build categories and classify novel objects within them. Even for completely unnecessary classifications like male or female human faces (Bhatt, Wasserman, Reynolds, & Knauss, 1988). Taking this into account it can be concluded that ravens have a preference for natural objects and caracaras have a preference for natural objects, but keas are attracted equally by all novel objects.

It would be desirable to run this test on more individuals to get a clear correlation from the measurements (see **fig. 6**). Also further investigations are needed to find out the reasons for the preferences in ravens and caracaras.

5.1.3 Problem solving

The problem solving experiment revealed several significant and some tended differences between all three species. The differences in problem solving abilities might be a hint for different levels of cognitive abilities amongst caracaras and the two other species. In the following discussion of the experimental results the three measured latencies (A, B, C) and the number of contacts with the box are discussed first, emphasizing on differences between the species. Following this, some more general conclusions are presented.

For latency A (the approach latency) no statistical significant result or tendencies were obtained during statistical analysis between the three species across all stages. This is not unexpected, since differences in the testing situation (two ore one individual tested simultaneously) come into effect most dominantly for this latency measure, and might induce a bias (see 5.2.4 Problem solving). However, the two caracaras had undisturbed testing situations and can be compared well. Furthermore, there was little interference between the ravens. For both of the caracaras latency A is longest in stage 1 (see **fig. 11**). This might be due to habituating to the new experimental setup, but with a clear decrease in the following four stages. The ravens had the longest measures for Latency A (see **fig. 7**) but with very strong differences between stages. Taking into account that Latency A is sometimes prolonged due to interference between the individuals in the keas the difference between ravens and the other species would be even greater in a standardized experimental setup. The extended approach latencies are probably induced by the strong neophobia in the ravens (see 4.1.2.1 Ravens).

For latency B (the contact latency) the keas had had a significantly shorter contact latency than ravens and tended to be faster than caracaras. The keas usually went to the box directly, when they had approached it within the 10 cm range and showed great curiosity towards the different experimental setups: e.g. latency B is 0 sec for stage 4 and generally stays below 1.5 sec (see **fig 9**). The difference between keas and caracaras is less evident, but the mean of latency B is a bigger for the caracaras. The keas show only little variations for latency B between the 5 stages, the same is true for the caracaras, but for the ravens large differences exist. A possible explanation is the strong level of neophobia in ravens. Adjusting to the changes in the setups of the different stages may have led to a delay in the contact latency.

Latency C (the consumption latency) is the most informative of all measured parameters, since it reveals how long it took the individual or species to solve the setup of the respective stage. Thus, allowing for some conclusions about the cognitive abilities of the birds. Despite the fact that no significant differences in consumption latency existed between the five different setups of the problem solving experiment (see **fig. 15**) stage 5 took longest to solve for all species and five out of six individuals: Keas and ravens needed similarly long (57 and 55 sec) but only between 5 and 13 sec to solve the setup of stage 1 to 4. The caracaras needed 101 sec for stage 5. Unlike the ravens and keas, no clear tendency for stage 1 to 4 exists for the caracaras (see **fig. 9**). Surprisingly the latencies for stage 1 and 2, where visual access to the food was available, were longer than for stage 3 and 4 in the caracaras.

Between the keas and ravens no measureable difference existed. But keas had significantly shorter consumption latency than caracaras and the ravens tended to be faster than the caracaras. The problem solving performance of the caracaras was inferior to keas and ravens, which supports the hypothesis that cognitive differences exist between the three species. This is discussed more detailed in 5.1.5 Review of the hypotheses. Interestingly these differences were most evident when stage 1 to 4 are compared between the three species. The differences within species were small in keas and ravens (see **fig. 13**), apart from the fact that Ivan, the female raven, did not participate in stage 1, 3 and 5 (see 5.2.4 Problem solving). But between the two caracaras striking differences exist for nearly all stages. Especially in stage 1 and 2 Donut, the male, needed much longer than the female (as for latencies A and B). Along with the findings form the neophobia test, where it was evident that Donut was more neophobic, a possible explanation might be that the habituation might have been too short. Which could have led to a longer durations of latency A to C in the first two trials. Or indeed actual differences exist amongst the two individuals in physical intelligence with Muffin being superior to Donut. What speaks against the later explanation is the comparison of latency C for stage 5 between the two caracaras: Donuts measurements are slightly lower than that of Crusty, the male kea, and are below the average times, which he needed to solve stage 1 and 2. Where else Muffin, the female was able to solve this setup only once, and most likely by chance (see 5.2.4 Problem solving). In this one successful trial out of five testing days she needed 3.9 times longer than Donut. All the other testing subjects needed longest to solve stage 5. It is likely that Donut would have needed shorter for stage 1 and 2, than for stage 5, too, would he have been habituated longer.

During the problem solving experiment the ravens needed significantly less contacts than the caracaras. The keas tended to need less contacts than the caracaras (see **fig. 10**). The number of contacts is generally small for ravens and keas, with a slightly elevated mean in stage 5 for both of them. The overall number of contacts is not greater than 3.35 (stage 1 for the caracaras). The minimal possible amount of contacts was achieved by the ravens in stage 2 and 3 and for the keas in stage 1 and 4. Explanations that can account for the little amount of contacts are a fast solving of the problem, persistent proceeding, or neophobia. For the keas good problem solving abilities and persistent proceeding account for the small number of contacts, the same is true for the ravens, but their behaviour seemed always very goal directed, not making unnecessary contact with the box. The caracaras sometimes needed very long and lost interest in the box, but came back later, to try again to open the box. The differences between individuals of the same species were little in keas and ravens. Only in stage 1 and 2 Donut, the male caracara, needed longer, than the conspecific female (see **fig. 14**). Probably the same explanation as for the other latencies is true (see text above).

In conclusion it can be said that significant differences existed between the three examined species. This work presents evidence that the striated caracara (*P. australis*) has the abilities to solve complex problem solving setups, but to a fewer extend than the common raven (*C. corax*) and kea (*N. notabilis*): for the most meaningful parameters in terms of physical problem solving abilities (Latency C and the number of contacts) no differences were measureable between keas and ravens, but keas and ravens performed better than caracaras. The findings correspondent with literature, where problem solving abilities are described for *C. corax* (Emery, 2006; Heinrich, 1995a), *N. notabilis* (Auersperg, von Bayern, et al., 2011; Werdenich & Huber, 2006) and *M. chimango* (Biondi et al., 2010) (closely related to *P. australis*). A general lack of ethological literature about *P. australis* exists and problem solving capacities have therefore not been reported before for this species.

5.1.4 Review of the hypotheses & integrated discussion

The collected data of this work confirm four of the six working hypotheses (1.5.1 Working hypotheses) and two had to be rejected. The results are compared to each hypothesis in the text below and some additional conclusions are drawn.

Hypothesis i): 'Keas are not neophobic, raven are neophobic, caracaras range in between but show clear tendency towards non-neophobic behaviour. '
This hypothesis is confirmed by the collected data. However caracaras did not range in between the two other species, but were clearly not neophobic. Differences between the tested individuals existed in the caracaras, but not in keas and ravens.

Hypothesis ii): 'Keas and caracaras show great explorative behaviour, raven show little explorative behaviour. '
This hypothesis had to be rejected, all three species showed similar explorative behaviour. The exploration time was longest for the ravens and shortest for the keas. But the number of contacts during the object exploration experiment was lowest for the ravens and highest for the keas.

Hypothesis iii): 'The exploring behaviour of the species differs in exploration time, number of contacts and preference for natural or unnatural objects.'
This hypothesis can be confirmed partly and rejected partly by the data. Little differences existed for exploration time (see hypothesis ii) but for the two other parameters differences are evident: Clear differences for preferences towards natural objects for ravens and unnatural objects for caracaras could be observed both, in exploration time and number of contacts. No preference was evident for keas.

Hypothesis iv): 'Caracaras are able to solve advanced experimental setups similarly to keas and raven.'
This hypothesis is confirmed by the collected data. The problem solving experiment showed, that caracaras are able to solve an advanced problem solving experiment, consisting of two steps (removing a bold and sliding a lid afterwards). But differences were apparent in the time, which was necessary to solve this setup, also differences between individuals of the same species were large sometimes.

Hypothesis v): ‘To solve a more complicated experimental setup will take more time for any species.’
This hypothesis had to be rejected. Statistical analysis revealed no significant differences in the latency to consumption between the five stages in the problem solving experiment. But for keas and ravens a tendency in stage 5 being more difficult than stage 1 to 4 could be observed.

Hypothesis vi): ‘There are differences in the ability to solve complex experimental setups between the species.’
This hypothesis is confirmed by the data. Keas performed significantly faster in the problem solving experiment and ravens tended to be faster, than the caracaras. Hence keas and ravens have more sophisticated problem solving abilities and a greater physical intelligence.

Between the three species significant differences in the duration necessary to solve the experimental stages during problem solving existed (see **fig. 9**). This indicates a higher level of physical cognitive skills in keas and ravens. However, it would be an incorrect assumption to generalize these findings to cognitive skills altogether, since cognition fans out across various domains (such as physical intelligence, social intelligence or memory, see 1.3. Problem solving)
In stage 3 to 5 of the problem solving experiment no visual access to the food was possible any more (see 3.4.2.3 Stage 3). And it was argued, that Piagetian object permanence would be a necessary prerequisite for solving such a setup (1.5 Aim of the study & Predictions). The ability to see the food being placed in the box and remembering its existence in the box gives evidence for stage 4 or higher Piagetian object permanence. However, another explanation could yield the same effect: learning that there is always food in the box. A possible solution, to check for this assumption would be i) to start with stage 3 to 5, so that the individuals would have no possibility to learn that food is presented in the box during every trial or ii) to include trials, where an empty box is shown to the birds, which is than closed. If the birds would show different reactions to these non-filled boxes Piagetian object permanence of stage 4 or higher could be assumed. Nevertheless, this level of object permanence seems to be necessary for remembering the existence of a cached object (Pepperberg & Funk, 1990) and caracaras as well as ravens do cache food (del Hoyo et al., 1994). An argument that supports learning is a decrease in the approach latency (see **fig. 7**) and the contact latency (see **fig. 8**) from stage 1 to 5 respectively stage 2 to 5 in the caracaras (see **tab. 7**). For ravens and keas Piagetian object permanence of the highest possible stage 6 has been showed elsewhere already (Bugnyar et al., 2007; Rahde, 2014).

5.1.5 Suggestions for enrichment

The here presented work gives evidence for advanced cognitive abilities in all three species, which clarifies the demand for enrichment to increase animal welfare (see 1.4 Zoos in research). Since all the animals show distinct exploratory behaviour enrichment does not necessarily has to be linked to food reward (e.g. hidden food). It is suggested to enrich the aviaries by regular changing elements in them. The caracaras tended to show a preference for unnatural objects, and the ravens tended to show a preference for natural objects (see 4.2 Object exploration) this could be taken into account, when designing enrichment for the species. For the caracaras e.g. balls of clothes, a swing and so on, for the ravens recombination of already known objects or natural, unknown objects For the keas both seems suitable. Introduction of very unfamiliar objects (in colour or material) to the ravens might induce stress, instead of increasing wellbeing.

5.2 Discussion of the Methods

In the following I will discuss the methods used in the different experiments, and highlight possible drawbacks of the applied methods.

5.2.1 General remark

A general problem with research is, that the experimenter unconsciously or unwillingly can influence the subjects of research. The experimenter could bias the results he is expecting, this effect is named after Rosenthal (Rosenthal & Fode, 1963). The effect can be diminished by adapting the experimental design, e.g. working with a (double) blind study experimental setup. For this thesis it would have been possible to anonymize the data before interpretation, but it was renounced, for the sake of practicability.

5.2.2 Neophobia test

The neophobia test applied in this study was based on literature (Biondi et al., 2010; Greenberg, 1984) with only small changes in the neophobia testing object (NTO) and no changes in the rest of the setup (see 3.2 Neophobia test). Except for the caracaras, the birds (i.e. ravens, keas) were tested as pairs for three reasons:

i) This matches their normal social living-context in the zoo during the testing period. Also the separation could have had unforeseen effects like increasing neophobia (Fritz & Kotrschal, 1999).

ii) Changing two factors (separation of birds and presence of the NTO) at once makes it hard to determine a cause and effect relationship.

iii) The ravens and keas aviaries simply hold no possibility to separate the birds and simultaneously introduce the NTO.

For the ravens the test as a pair made no difference, since no interaction with the NTO, the food or inferring behaviour could be observed. For the keas some interaction between the two individuals occurred (see 4.1 Neophobia test). Still, the applied setup revealed clear results, which are consistent with literature. Also the use of the duration of the habituation phase during problem solving is a valid measure for neophobic and neophilic behaviour, since the results resemble these of the neophobia test.

5.2.3 Object exploration test

In the object exploration test 6 novel objects of two categories were presented to the individuals. The object exploration test was based on literature and aside from the spinal bone and the metal bowl the objects were adopted as described by Biondi and colleagues (Biondi et al., 2010). Testing several individuals with only two objects (stimuli) does not test the results of the two categories of the stimuli (e.g. natural/unnatural object), but tests the differences between these two specific objects only. The categories have to be presented through several objects from the same category instead to prevent pseudoreplication (Hurlbert, 1984). Therefore three objects were chosen per category.

To adopt the use of the walnut as one of the natural objects from literature was an unlucky decision: Caracaras are omnivorous, but seemingly show little interest into cracking nuts, in contrast to the other two bird species: One of the ravens tried to cache the nut (see 4.2 Object exploration) and the female kea was able to crack it open. This might have possibly increased the times which were measured for natural objects. But it has to be kept in mind that the birds were fully satiated prior to testing. Hunger might not have been the motivation for contact with the walnut but maybe the motivation to cache this nut, which is reported for ravens (del Hoyo et al., 2009) and caracaras (del Hoyo et al., 1994). The walnut was not an unknown object for ravens and caracaras (but they had not seen unhalved walnuts before) and might therefore be less attractive than an unknown object for a neophilic bird in terms of exploring something new, but more attractive in terms of obtaining already known food.

The caracaras were housed separately during research and the keas could be separated for the 15 min duration of the object exploration test. Again there was no option to separate the ravens since their aviary holds no such option. Therefore the ravens were tested together. There was no direct and very little indirect interaction between the two individuals (see 4.2 Object exploration). The Zoo is not a perfect environment for research, but much better, than the wild. The display for visitors plays a predominant role. Still very clear differences in object exploration behaviour could be assessed and there was little interference between the ravens.

5.2.4 Problem solving test

Various adaptions had to be made to meet the requirements of the different holding conditions of the three tested bird species. The interference amongst the birds and the non-willingness of Ivan, the female raven, to participate in the experiment along with several essential changes during the experiment (see **tab. 2**) led to a non-standardized experimental setup. These adaptions and some points concerning the design of the experiment will be addressed in the following section. Nonetheless, the problem solving experiment delivered several significant and interesting results.

A Friedman-ANOVA revealed no statistical significant differences for latency C (the time it took the birds to open the box and obtain the food) across the five stages between the three species (see 4.3 Problem solving). This suggests that there was no significant difference in the difficulty to obtain the food between the stages. However, this does not preclude the existence of difference amongst the five stages: Only successful trials, i.e. trials where the food was obtained, could be used to compute the differences in latency C. Muffin, the female caracara, was able to solve stage 5 only once and this was by mere luck, because the bolds fell out after 5 min of pecking and pushing the box around. She was not able to succeed again within the five following sessions. Therefore it is acceptable to say that for Muffin stage 5 was more difficult to solve than the previous stages, where here success rate was equal to the other birds. Also for the ravens and keas elevated durations of latency C were apparent (see **fig. 9**). Taking this into account plus the fact, that Muffin failed in stage 5, suggest that at least Stage 5 had an elevated level of difficulty. Stage 1 to 4 seemed to be similarly difficult to solve for the birds.

The amount of trials per species, necessary to obtain statistical relevant results also depends very much on the differences between cognitive skills of the investigated species. Making out huge differences is easier, than finding small ones. That in this setup only some significant differences between the species could be observed, could therefore be due to a lack of a sufficient number of trials. On the other hand, it could also indicate similarly good problem solving capacities in all three species. On average 15.1 successful trials were conducted per species and stage. Raising the number of trials considerably would reduce the standard deviation and standard error which could result in more significant results. But a difference of e.g. 1 sec in latency C would not be meaningful, even though it could be statistically significant.

The keas and ravens had to be tested simultaneously, since it was not possible to separate them. Also there are good reasons not to separate them (see 5.2.2 Neophobia test).

This is maybe the biggest inconsistency in these experiments between species. As the two keas often interfered the measurements of latency A and B for the keas have to be interpreted with caution. A longer latency A could be due to events like the male first approaching the second box, but returning to the first one soon after. Similarly a longer latency B could be due to behaviour like approaching a box within the 10 cm range (see **fig. 1**) but taking interest in or being delayed by the other individual. As for latency C: the trials were only used for later analysis, if from first contact with the box no interference occurred any more.

5.2.5 Statistical analysis

The mean of latency A, B, C and the number of contacts was calculated using all measured latencies from male and female of the given species. The data points of the successful trials were cumulated and divided by the total number of successful trials of both individuals. This method gives an accurate SE but in case the number of conducted trials is not equal for both individuals the impact of one of the individuals might be dominant. On the other hand weighting e.g. 1 measurement from the female caracara in stage 5 as strong as 10 from the male distorts the data even more. Therefore it was decided to pool all measurements per species for calculating mean and SE.

A Friedman-ANOVA was used to compare the measurements of the latencies and the number of contacts, due do small sample size (in average 15.1 successful measured trials per stage and species) and nonparametric distribution. But there is a drawback with using this nonparametric test: it can compare only samples, which do not differ in sample size (which is the case for the data of the problem solving test). The solution for this problem is described in 5.2.5 Statistical analysis. This reduced the sample size further, leaving five depending variables (one per stage) but the number of independent variables (species) stayed constant. Thus the sensitivity of the test is reduced. The same is true for the Friedman-ANOVA checking for differences in difficulty between the stages, where three dependent variables could be tested (species) against five independent variables (respective stage).

An equal sample size of every test subject in every condition would therefore have been desirable. However, as the birds were not food or water deprived for testing, or otherwise forced to participate, I could only rely on the subjects taking part in the experiments voluntarily.

5.3 Conclusion & Perspective

In conclusion it can be said that the here presented work yielded interesting results and that comparative studies are a good option to learn about species, especially if a lack of literature exists. In some of the experiments huge differences existed between individuals of the same species, resulting in a large standard error. Increasing the sample size per species would allow to generalize these results and to create external validly, too. Still some of the results can be generalized to species level e.g. the find that *P. australis* possesses the ability to solve advanced physical problems and is a relative neophilic species.

It turned out that the duration, required for the habituation during the problem solving experiment is a good test to double-check the results of a neophobia test. Thus it is recommended for further research, to compare these two measures, if both tests are conducted on the same individuals. Also a problem solving experiment, which uses 5 stages could be made more efficient by reducing the amount of stages to a lower number, e.g. three. Another suggestion is to include one experimental setup, which is very hard or impossible to solve for comparing peak performance amongst the birds whereby a clear graduation of individuals could be achieved.

Further investigations are needed to locate the reasons for surprising preferences to natural objects in ravens and the preference for unnatural objects in caracaras. It would be extremely interesting to explore, if these findings can be generalized for *C. corax* and *P. australis*.

This work gives evidence, that the phylogenetic reorganisation of the Falconiformes into the Eufalconimorphae clade, together with the Passeriformes and Psittaciformes is matched not only by genetic descent, but by a similarly high level of physical intelligence, too.

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7 LIST OF ABREVIATIONS

CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora

EAZA – European Association of Zoos and Aquaria

EEP – Europäische Erhaltungszuchtprogramme

IUCN – International Union for Conservation of Nature

NTO – Neophobia testing object

7.1 Name Index

Common raven – *Corvus corax*
Randall ♂
Ivan ♀

Kea – *Nestor notabilis*
Crusty ♂
Maggie ♀

Striated Caracara – *Phalcoboenus australis*
Donut ♂
Muffin ♀

8 APPENDIX

Neophobia test

Species	*Corvus corax*		*Phalcoboenus australis*		*Nestor Notabilis*	
Individual	♂	♀	♂	♀	♂	♀
Latency to consumption [min:sec]	15:00	15:00	2:07	0:07	0:01	0:01
Mean [min:sec]	15:00		1:08		0:01	
SE [min:sec]	0:00		1:01		0:00	

Tab. 3: Values of the Neophobia test; since the kea touched the NTO even before the slider of the aviary was closed (start of the measuring of elapsed time) the minimum value of 1 sec was noted down; see 4.4.1 Neophobia test

Object exploration: contact duration

Species	*Corvus corax*		*Phalcoboenus australis*		*Nestor Notabilis*	
Individual	♂	♀	♂	♀	♂	♀
Walnut	5:11	1:51	0:00	0:50	0:28	2:35
Spinal bone	0:00	0:00	0:11	0:52	0:03	0:15
Snail shell	0:18	0:00	0:03	0:14	0:00	0:14
Total	5:29	1:51	0:14	1:56	0:31	3:04
Mean	3:40		1:05		1:48	
SE	1:49		0:51		1:17	
Cupboard box	2:35	0:00	1:45	1:31	0:16	1:29
Plastic lid	0:00	0:00	1:19	2:43	0:21	1:13
Steel bowl	0:00	0:00	0:41	0:25	0:13	0:12
Total	2:35	0:00	3:45	4:39	0:50	2:54
Mean	1:18		3:52		1:52	
SE	1:18		0:48		1:02	

Tab. 4: Duration [min:sec] of contacts with the objects used in the object exploration test for all birds; Mean and SE are calculated per species and categories (natural and unnatural objects)

Object exploration: number of contacts

Species	*Corvus corax*		*Phalcoboenus australis*		*Nestor Notabilis*	
Individual	♂	♀	♂	♀	♂	♀
Walnut	9	4	0	6	2	8
Spinal bone	0	0	3	5	1	7
Snail shell	2	0	1	3	0	4
Total	11	4	4	14	3	19
Mean	7.5		9.0		11.0	
SE	3.5		5.0		8.0	
Cupboard box	4	0	3	5	4	8
Plastic lid	0	0	3	7	4	4
Steel bowl	0	0	5	5	2	6
Total	4	0	11	16	10	18
Mean	2.0		13.5		14.0	
SE	2.0		2.5		4.0	

Tab. 5: number of contacts with the objects used in the object exploration test for all birds; Mean and SE are calculated per species and categories (natural and unnatural objects)

Problem solving: *Corvus corax*

		Mean		N			
Stage	Parameter	♂	♀	♂	♀	Species Mean	Species SE
1	Lat. A*	12.07	-	15	-	12.07	1.37
	Lat. B*	1.67	-			1.67	0.49
	Lat. C*	9.13	-			9.13	3.40
	No. of contacts**	1.20	-			1.20	0.20
2	Lat. A*	10.33	0.00	9	3	7.75	2.27
	Lat. B*	1.56	1.00			1.417	0.45
	Lat. C*	6.67	7.33			6.83	1.71
	No. of contacts**	1.00	1.00			1.00	0.00
3	Lat. A*	38.88	-	8	-	38.88	10.39
	Lat. B*	16.38	-			16.38	12.74
	Lat. C*	13.38	-			13.38	3.38
	No. of contacts**	1.00	-			1.00	0.00
4	Lat. A*	15.50	6.33	6	6	10.91	2.77
	Lat. B*	2.17	9.83			6.00	4.66
	Lat. C*	16.17	6.17			11.17	2.91
	No. of contacts**	1.33	1.00			1.17	0.17
5	Lat. A*	12.17	-	6	-	12.17	2.82
	Lat. B*	3.17	-			3.17	1.64
	Lat. C*	55.33	-			55.33	19.76
	No. of contacts**	1.67	-			1.67	0.49

Tab. 6: * given in sec + two decimal places; ** given in total number + two decimal places

Problem solving: *Phalcoboenus australis*

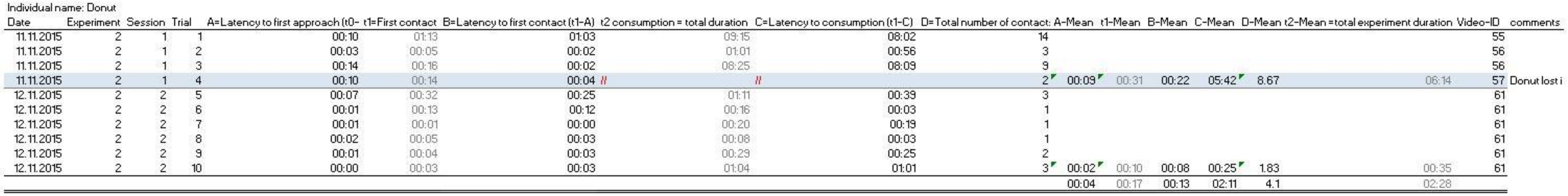
		Mean		N			
Stage	Parameter	♂	♀	♂	♀	Species Mean	Species SE
1	Lat. A*	44.93	10.33	14	14	27.03	5.78
	Lat. B*	4.64	2.21			3.43	0.55
	Lat. C*	93.57	17.60			54.28	16.45
	No. of contacts**	5.79	1.07			3.35	0.77
2	Lat. A*	4.33	0.17	9	6	2.67	1.10
	Lat. B*	12.56	0.67			7.80	4.29
	Lat. C*	130.78	11.00			82.87	42.47
	No. of contacts**	4.11	1.00			2.87	0.96
3	Lat. A*	1.50	0.17	6	6	0.83	0.30
	Lat. B*	5.50	0.67			3.08	1.78
	Lat. C*	21.33	18.67			20.00	4.93
	No. of contacts**	1.67	1.17			1.42	0.19
4	Lat. A*	2.18	3.56	11	9	2.80	0.83
	Lat. B*	2.73	3.22			2.95	0.82
	Lat. C*	17.55	53.22			33.60	6.98
	No. of contacts**	1.36	1.67			1.50	0.17
5	Lat. A*	1.00	0.00	9	1	0.91	0.72
	Lat. B*	1.90	1.00			1.82	0.70
	Lat. C*	79.70	311.00			100.73	27.54
	No. of contacts**	1.80	1.00			1.77	0.24

Tab. 7: * given in sec + two decimal places; ** given in total number + two decimal places

Problem solving: ***Nestor notabilis***

		Mean		N			
Stage	Parameter	♂	♀	♂	♀	Species Mean	Species SE
1	Lat. A*	8.53	9.40	15	5	8.75	2.78
	Lat. B*	1.47	1.80			1.55	0.54
	Lat. C*	6.00	2.80			5.20	1.08
	No. of contacts**	1.00	1.00			1.00	0
2	Lat. A*	16.12	4.29	17	7	12.67	3.71
	Lat. B*	0.88	2.29			1.29	0.48
	Lat. C*	8.76	4.86			7.63	1.88
	No. of contacts**	1.24	1.14			1.21	0.09
3	Lat. A*	2.20	5.00	10	6	3.25	1.16
	Lat. B*	0.40	0.67			0.50	0.13
	Lat. C*	4.00	12.00			7.00	2.73
	No. of contacts**	1.00	1.17			1.06	0.06
4	Lat. A*	3.67	8.86	6	7	6.46	2.42
	Lat. B*	0.00	0.00			0.00	0.00
	Lat. C*	10.33	3.57			6.69	2.98
	No. of contacts**	1.00	1.00			1.00	0
5	Lat. A*	7.50	0.43	6	7	3.69	2.20
	Lat. B*	0.67	1.58			1.154	0.478
	Lat. C*	80.00	37.00			56.85	14.92
	No. of contacts**	1.50	1.86			1.69	0.26

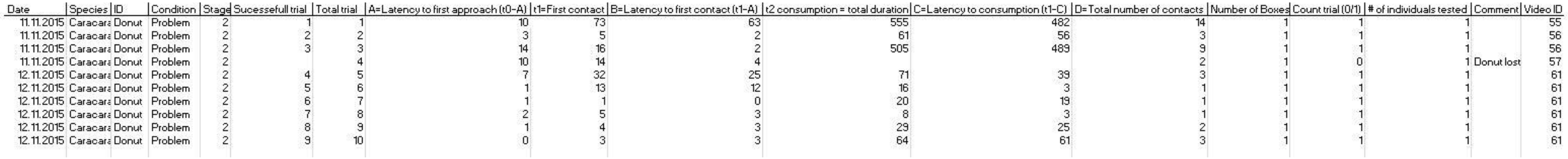
Tab. 8: * given in sec + two decimal places; ** given in total number + two decimal places



Individual name: Donut

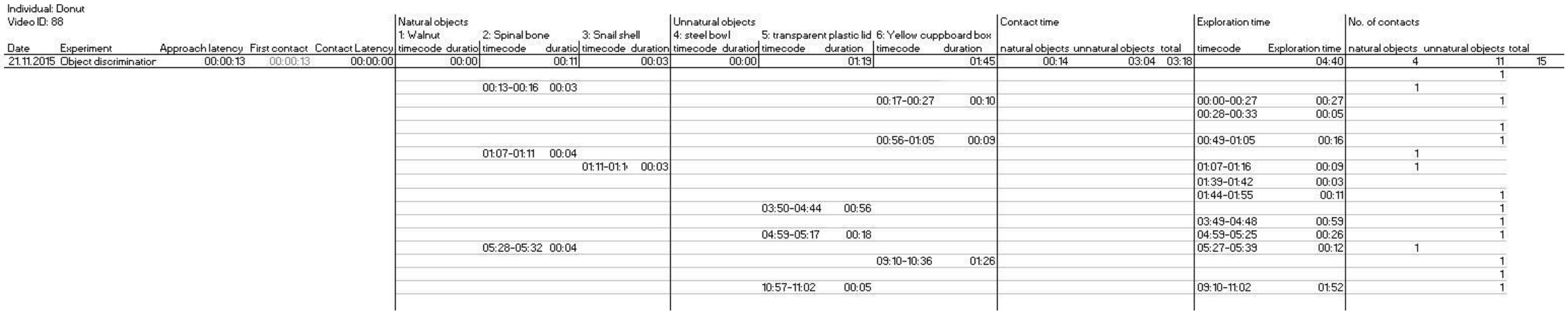
Date	Experiment	Session	Trial	A=Latency to first approach (t0-	t1=First contact	B=Latency to first contact (t1-A)	t2 consumption = total duration	C=Latency to consumption (t1-C)	D=Total number of contact:	A-Mean	t1-Mean	B-Mean	C-Mean	D-Mean	t2-Mean =total experiment duration	Video-ID	comments
11.11.2015	2	1	1	00:10	01:13	01:03	09:15	08:02	14							55	
11.11.2015	2	1	2	00:03	00:05	00:02	01:01	00:56	3							56	
11.11.2015	2	1	3	00:14	00:16	00:02	08:25	08:09	9							56	
11.11.2015	2	1	4	00:10	00:14	00:04	//	//	2	00:09	00:31	00:22	05:42	8.67	06:14	57	Donut lost i
12.11.2015	2	2	5	00:07	00:32	00:25	01:11	00:39	3							61	
12.11.2015	2	2	6	00:01	00:13	00:12	00:16	00:03	1							61	
12.11.2015	2	2	7	00:01	00:01	00:00	00:20	00:19	1							61	
12.11.2015	2	2	8	00:02	00:05	00:03	00:08	00:03	1							61	
12.11.2015	2	2	9	00:01	00:04	00:03	00:29	00:25	2							61	
12.11.2015	2	2	10	00:00	00:03	00:03	01:04	01:01	3	00:02	00:10	00:08	00:25	1.83	00:35	61	
										00:04	00:17	00:13	02:11	4.1	02:28		

Pic. 11: Excel-sheet for collecting data of one individual during the problem solving experiment (here containing sampling data from Donut, the male caracara; the bluish line indicates a measure that was excluded from later analysis); the data collected for each trial are: date; stage number (1-5); session (each day of a stage represents a new session); trial (sequential numbers starting from 1; also failed trials); latency A, B, C (see 3.4.3 Measured parameters for detailed descriptions of the latencies A, B, C), time of first contact (t1); time of consumption (t2); total number of contacts; potential comments and the video indexing number; the mean was calculated for each session and for each stage



Date	Species	ID	Condition	Stage	Sucessefull trial	Total trial	A=Latency to first approach (t0-A)	t1=First contact	B=Latency to first contact (t1-A)	t2 consumption = total duration	C=Latency to consumption (t1-C)	D=Total number of contacts	Number of Boxes	Count trial (0/1)	# of individuals tested	Comment	Video ID
11.11.2015	Caracar	Donut	Problem	2	1	1	10	73	63	555	482	14	1	1	1		55
11.11.2015	Caracar	Donut	Problem	2	2	2	3	5	2	61	56	3	1	1	1		56
11.11.2015	Caracar	Donut	Problem	2	3	3	14	16	2	505	489	9	1	1	1		56
11.11.2015	Caracar	Donut	Problem	2		4	10	14	4			2	1	0	1	Donut lost	57
12.11.2015	Caracar	Donut	Problem	2	4	5	7	32	25	71	39	3	1	1	1		61
12.11.2015	Caracar	Donut	Problem	2	5	6	1	13	12	16	3	1	1	1	1		61
12.11.2015	Caracar	Donut	Problem	2	6	7	1	1	0	20	19	1	1	1	1		61
12.11.2015	Caracar	Donut	Problem	2	7	8	2	5	3	8	3	1	1	1	1		61
12.11.2015	Caracar	Donut	Problem	2	8	9	1	4	3	29	25	2	1	1	1		61
12.11.2015	Caracar	Donut	Problem	2	9	10	0	3	3	64	61	3	1	1	1		61

Pic. 12: Pivot-table for pooling the data of all individuals for the problem solving experiment (here containing sampling data from Donut, the male caracara): the data collected in the table are: Date of experiment; the species; ID (name of the individual); condition (habituation or actual experiment); Stage number (1-5); Successful trial (continuous numbering of trials per stage, that can be used for statistical analysis); total trial (continuous numbering of trial per stage); latency A, B, C (see 3.4.3 Measured parameters for detailed descriptions of the latencies A, B, C), time of first contact (t1); time of consumption (t2); total number of contacts; number of boxes simultaneously used; Count trial (unsuccessful trials were sorted out before statistical analysis was conducted); number of individuals tested (generally 1 for the caracaras and 2 for keas and raven); comments; video-ID



Individual: Donut
Video ID: 88

					Natural objects						Unnatural objects						Contact time			Exploration time		No. of contacts		
					1: Walnut		2: Spinal bone		3: Snail shell		4: steel bowl		5: transparent plastic lid		6: Yellow cuppboard box									
Date	Experiment	Approach latency	First contact	Contact Latency	timecode	duratio	timecode	duratio	timecode	duration	timecode	duratior	timecode	duration	timecode	duration	natural objects	unnatural objects	total	timecode	Exploration time	natural objects	unnatural objects	total
21.11.2015	Object discriminatior	00:00:13	00:00:13	00:00:00		00:00		00:11		00:03		00:00		01:19		01:45	00:14	03:04	03:18		04:40	4	11	15
																							1	
							00:13-00:16	00:03														1		
															00:17-00:27	00:10				00:00-00:27	00:27		1	
																				00:28-00:33	00:05			
																							1	
															00:56-01:05	00:09				00:49-01:05	00:16		1	
							01:07-01:11	00:04														1		
									01:11-01:1	00:03										01:07-01:16	00:09	1		
																				01:39-01:42	00:03			
																				01:44-01:55	00:11		1	
													03:50-04:44	00:56									1	
																				03:49-04:48	00:59		1	
													04:59-05:17	00:18						04:59-05:25	00:26		1	
							05:28-05:32	00:04												05:27-05:39	00:12	1		
															09:10-10:36	01:26							1	
																							1	
													10:57-11:02	00:05						09:10-11:02	01:52		1	

Pic. 13: Excel-sheet for collecting data of individuals during the object exploration experiment (here containing sampling data from Donut, the male caracara), the table contains: name of individual; video-ID; the experiment name; approach latency A; time of first contact; contact latency B; in two supersets the data for natural and unnatural objects are organized, for each of the six objects the timecode in the video and the duration of contact is included; contact time with natural, unnatural and cumulative contact time is included; exploration time (range spend in 10 cm radius of any of the objects and its timecode is included; number of contacts with natural and unnatural objects and total number of contacts is included

9 LITERATURE

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