COMENIUS UNIVERSITY IN BRATISLAVA

FACULTY OF MATHEMATICS, PHYSICS AND INFRORMATICS

Kea and The Ephemeral Reward Task:

Success and Hurdles Explored

Diploma thesis

2020

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Study programme: Cognitive Science

Field of study: Computer Science

Department: Department of Applied Informatics

Consultant: Raoul Schwing, Phd.

Supervisor: RNDr. Barbora Cimrová, Phd.

2020 **Bc. Peter Šebáň**

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THESIS ASSIGNMENT

Name and Surname:	Peter Šebáň
Study programme:	Cognitive Science (Single degree study, master II. deg., full time form)
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Title: Kea and the ephemeral reward task: success and hurdles explored

Annotation: In the ephemeral-reward task a subject has a possibility to choose between stimuli A and B. Each of them contains an identical reward (food). The subject can opt for the stimuli A what would result in obtaining the reward linked to A and the trial is finished. The same applies when the subject opts for the stimuli B: it receives the reward linked to B. However, here the subject can get also a reward linked to A (Zentall & Case, 2018). The ideal scenario for a subject is therefore to select the stimulus B.

Aim: Perform and evaluate an experiment of the ephemeral-reward task on the New Zealand parrot Kea (Nestor Notabilis).

Literature: Salwiczek, L. H., Prétôt, L., Demarta, L., Proctor, D., Essler, J., Pinto, A. I., Wismer, S., Stoinski, T., Brosnan, S. F., & Bshary, R. (2012). Adult cleaner wrasse out-perform capuchin monkeys, chimpanzees, and orangutans in a complex foraging task derived from cleaner client reef fish cooperation. PLOS ONE, 7(11)
Zentall, T. R., Case, J. P. (2018). The Ephemeral-Reward Task: Optimal Performance Depends on Reducing Impulsive Choice. Current Directions in Psychological Science,1-7
Zentall, T. R., Case, J. P., & Luong, J. (2016). Pigeon's (Columba livia) paradoxical preference for the suboptimal alternative in a complex foraging task. Journal of Comparative Psychology, 130, 138–144.

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ZADANIE ZÁVEREČNEJ PRÁCE

Meno a priezvisko študenta:	Peter Šebáň
Študijný program:	kognitívna veda (Jednoodborové štúdium, magisterský II. st., denná forma)
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Typ záverečnej práce:	diplomová
Jazyk záverečnej práce:	anglický
Sekundárny jazyk:	slovenský

Názov: Kea and the ephemeral reward task: success and hurdles explored
Kea a efemérna úloha: skúmanie úspechov a prekážok

Anotácia: Princíp efemernej úlohy spočíva v poskytnutí možnosti výberu medzi podnetom A a podnetom B. Každý z týchto podnetov obsahuje rovnakú odmenu. Ak si subjekt vyberie podnet A, získava odmenu, ktorá je naviazaná na tento podnet a pokusné kolo je ukončené. V prípade, že si subjekt vyberie podnet B, získava odmenu naviazanú na tento podnet. Avšak, v tomto prípade má príležitosť vziať si aj odmenu naviazanú na podnet A (Zentall & Case, 2018). Ako vyplýva z vyššie uvedeného, pre subjekt je najvýhodnejšie zvoliť si podnet B.

Cieľ: Vykonať a vyhodnotiť experiment efemérnej úlohy na novozélandskom druhu papagája Kea (Nestor Notabilis).

Literatúra: Salwiczek, L. H., Prétôt, L., Demarta, L., Proctor, D., Essler, J., Pinto, A. I., Wismer, S., Stoinski, T., Brosnan, S. F., & Bshary, R. (2012). Adult cleaner wrasse out-perform capuchin monkeys, chimpanzees, and orangutans in a complex foraging task derived from cleaner client reef fish cooperation. PLOS ONE, 7(11)
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Dátum schválenia: 27.02.2020

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.... študent

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Declaration

I hereby declare that I elaborated this diploma thesis independently using the cited literature.

Bratislava, 2020

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I would like to thank to my consultant Raoul Schwing for his immense support and patience. Through our conversations, I learned a lot not only about kea but also about cognition of animals in general.

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Abstract

SEBAN, Peter. Kea and The Ephemeral Reward Task: Success and Hurdles Explained. [Diploma Thesis]. – Comenius University in Bratislava. Faculty of Mathematics, Physics and Informatics; Department of Applied Informatics. – Consultant: Raoul Schwing, Phd. – Supervisor: RNDr. Barbora Cimrová, PhD. - Qualification Degree: Master. Bratislava: FMPH CU, 2020. 58p

New Zealand parrot species kea *(Nestor notabilis)* and their cognitive abilities are at the center of our research. Kea are well-known for their curiosity, complex social interactions and problem-solving. Their cognitive abilities were investigated in two different experimental tasks, both of them in two different settings. In the 'Two versus one quantity discrimination task', it was revealed that kea are able to discriminate between one piece of reward and two pieces of reward, however their performance was not as straightforward as expected. The main objective of our research was to explore the performance of kea on the Ephemeral reward task. It was revealed that despite difficulties, kea are able to solve this task. This intriguing task was solved only by a small number of other species. The general principle of the Ephemeral reward task is as follows: There is a permanent reward that can be chosen at any time, and an ephemeral reward which is removed, if not chosen first. Choosing the ephemeral reward first allows the choice of the permanent reward after, resulting in two rewards per trial. Choosing the permanent reward first, leads to the end of a trial and the gain of only one reward. Previous studies of the Ephemeral reward task on other species directed their focus on generating relevant ecological conditions of given species and on their impulsivity control. Our research also followed this direction and for that reason, two different experimental settings were employed.

Key words: animal cognition, kea *(Nestor notabilis)*, Ephemeral reward task, ecological relevance, decision making

Abstrakt

ŠEBÁŇ, Peter. Kea a Efemérna Úloha: Skúmanie Úspechov a Prekážok. [Diplomová Práca]. – Univerzita Komenského v Bratislave. Fakulta matematiky, fyziky a informatiky; Katedra aplikovanej informatiky. – Konzultant: Raoul Schwing, Phd. – Školiteľ: RNDr. Barbora Cimrová, PhD. – Stupeň kvalifikácie: Magister. Bratislava: FMFI UK, 2020. 58s

Náš výskum je zameraný na preskúmanie kognitívnych schopností novozélandského druhu papagája kea (*Nestor notabilis)*. Kea sú známe svojou zvedavosťou, komplexnými sociálnymi interakciami a schopnosťou riešiť veľké množstvo problémov. V našej práci, boli kognitívne schopnosti papagájov kea skúmané prostredníctvom dvoch experimentálnych úloh v dvoch rôznych prevedeniach. V experimentálnej úlohe zameranej na diskrimináciu množstva, bolo zistené, že kea sú schopné rozlišovať medzi dvoma kúskami odmeny a jedným kúskom odmeny, i keď s určitými problémami. Ďalej sa podarilo zistiť, čo bolo aj hlavným zámerom výskumu, že kea sú schopné pochopiť Efemérnu úlohu, v ktorej sa podarilo uspieť len malému množstvu iných druhov zvierat. Princíp efemérnej úlohy je nasledovný: subjekt má na výber z dvoch možností. Jedna možnosť – tzv. permanentná, ktorá môže byť zvolená kedykoľvek a tzv. efemérna, ktorá je odstránená, ak nie je zvolená ako prvá. Prakticky to znamená, že ak si subjekt vyberie efemérnu odmenu ako prvú, môže si následne zobrať aj permanentnú odmenu, čo znamená, že celkovo získa dve odmeny. Ak si však subjekt vyberie permanentnú odmenu ako prvú, testové kolo sa končí a subjekt teda v tomto kole získa iba jednu odmenu. Predošlé experimenty v oblasti efemérnej úlohy sa zamerali na vytvorenie relevantných ekologických podmienok pre daný druh zvierat a kontrolu impulzivity. V našom výskume bol tiež zvolený tento smer, a preto boli použité dve rôzne experimentálne podmienky, v ktorých experiment prebiehal.

Kľúčové slová: kognícia zvierat, kea *(Nestor notabilis)*, Efemérna úloha, ekologická relevancia, rozhodovanie

Table of contents

List of Figures

Introduction

People have been captivated by understanding the human mind for centuries. Earlier, the human mind was perceived as a soul of immaterial nature and bestowed on us by gods. After death of the body, this soul was still alive and would live forever either in different bodies or in paradise. With the emergence of scientific thinking, new hypotheses about the mind began to appear. The mind was no longer considered equal to soul but started to be understood as tightly connected with the brain. A number of new theories which attempted to explain how the mind could arise from the brain and enable our functioning in the world started increasing in popularity. However, recent theories emphasize not only the brain as an important structure for functioning but also the entire body. Hence the term cognition was introduced to encompass the entire process of functioning of an organism in the world. Humans as the species have been at the center of interest in the studying of cognitive abilities ever since. Research on animals was conducted only in order to help understanding human cognition. However, in the recent years, this strong anthropocentric view on cognition begins to fade in favor of the so-called biocentric view. No form of life is denied its inherent uniqueness; rather, cognitive abilities of these species are researched for the sake of understanding the species itself and understanding the cognition as a general biological phenomenon.

There is a great number of species that are researched in order to uncover their cognitive capabilities. One of these species is kea (*Nestor notabilis*). Kea are famous for their curiosity, social relations and playfulness. These are also the reasons why kea are included in a large variety of experiments researching cognition. Since kea are endemic species of New Zealand, in our geographical area, kea can only be found in captivity. One of these places is the Haidlhof research station situated near the town Bad Voslau in Austria. I first encountered kea when I was working on my Erasmus project and was instantly fascinated by their cognitive abilities and nature. In general, cognitive abilities of kea fascinate many scientists nowadays and despite a solid body of research already conducted, there is still a lot to explore. In particular, the main goal for this project is to explore cognitive abilities like learning, decision-making, simple quantity discrimination, inhibition of action and future planning of kea. For attaining this goal, the Ephemeral reward task and Two versus one quantity discrimination task in two different settings were employed. In order to understand what was carried out, the thesis comes in the following structure.

The first chapter introduces some important milestones that occurred in the history of human thinking and enabled the studying of animal cognition. The focus of this part goes from Aristoteles, Descartes, Darwin through the research carried out by behaviorists and psychologists to the modern research fields that attempt to abandon anthropocentric standpoint on cognition. Instead, they point out the biocentric view on cognition (comparative cognition and cognitive biology) and the need for ecological approach in researching cognition. In addition, enactivism as a philosophical framework will be introduced which also considers cognition as a process inherent to all animals and emphasizes species-specific environmental conditions. This introductory chapter further describes the idea of Ephemeral reward task as the task that lies in the center of our experiment. The principle of the task, its intriguing features, history of its origins, previous research conducted in the area, and the role of ecological factors will be presented. Afterwards, the area of research focusing on quantity discrimination in animals and the major findings in this field will be defined. This chapter will be concluded with defining the research questions, hypotheses as well as the predictions of our study.

The practical part begins with the note on ethical rules and is followed by the description of our participants – the kea parrots. Kea's appearance, behavior and cognitive abilities in general are described in detail in the next part. Since the kea participating in our experiment are captive, the focus of the next part is given on the description of their housing conditions at the Haidlhof research station in Bad Voslau. Subsequently, the two set-ups that were utilized in our experiments and the procedure of the experiments are described in detail. The results of this research are then analyzed in depth and its interpretation is provided in the discussion section. The master thesis is concluded with the summary and some further thoughts on the findings.

1 Animal cognition research

The theoretical part of the thesis introduces important events from the history that lead to the field of animal cognition to arise. Next, the background of the Ephemeral reward task is introduced, followed by the description of previous research conducted in this area. Then the research of quantity discrimination from the perspective of animal cognition research is introduced. At the end of this chapter, our research questions, hypotheses and predictions are presented.

1.1 From Aristotle to Darwin

Our anthropocentric perception of the world makes us feel that we, as human beings, are fundamentally different from all the other forms of life, especially in terms of cognitive abilities. Yet, thanks to the decades of research it now seems that human cognition is not so exclusive and superb. In fact, humans have already been pondering about the thinking abilities of other species for a long time. The well-known ancient thinker Aristotle can be considered as one of the first who mentioned such abilities in his work. According to an ancient commentator Sorabji (1995), Aristotle proposed the idea that animals have sensory perception, memory, desires, and even emotions. Moreover, he assumed that they might have the faculty of mind, also known as psyche.

Many centuries after Aristotle's era, two famous thinkers proposed their ideas that had changed the understanding of cognition in general and established the grounds for animal cognition research specifically. The ideas proposed by Rene Descartes (1637), underscored the anthropocentric view on human beings. In his philosophical writings, Descartes proposed that animals are mere machines and humans are fundamentally different from them. Moreover, he proposed that behavior and physiology of animals is controlled by intricate bodily mechanisms, but they lack a unique element for humans – the rational soul. The rational soul was in his view something that did not even reside within the human body. It was something divine, something that made humans unique and qualitatively different from other species. Thanks to the rational soul humans are capable of interpersonal communication and words usage, he claimed. Indeed, communication allows for the rise of intelligence and thinking capacities. But Descartes saw animals as only bound to respond innately (reflexively) without any ability to use intelligence. Nevertheless, the ideas of Descartes became a critical starting point for many thinkers who attempted to refute them.

It was Charles Darwin´s (1871) idea of organic evolution by natural selection that brought about a sweeping change in the understanding of origins of human beings and other species. For that era, the immensely controversial idea that human beings together with other animals share the same origin, faced harsh critique especially from the religious circles. In fact, this idea of common origin implicated that there should not be such a big difference in human and animal abilities. Contrary to Descartes, Darwin regarded communication and intelligence from the evolutionary perspective. He perceived many rudimentary and even advanced forms of both communication and intelligence throughout the entire animal kingdom. Apart from the obvious evolutionary continuity of bodily structures, Darwin also emphasized the continuity of mental capacities among humans and animals. Thanks to Darwin´s theory of evolution as a unifying component of biological sciences, the field of animal cognition could arise in the subsequent years, too. However, in the beginnings of scientific research of mind and cognition, the cognition of animals was explored only in order to reveal the principles of functioning and biological underpinnings of human mind.

1.2 The view of behaviorism and cognitivism on animal cognition

One of the first scientific fields researching mind and human functioning in the surrounding world was psychology. Especially, with the emergence of behaviorism, important advancement in research on animal (cognitive) capacities appeared as well. Acknowledging the Darwinian evolutionary perspective, animals were presumed to possess the same qualities as humans, only in different magnitude. As Watson (1913) suggested: “The behaviorist, in his efforts to get a unitary scheme of animal response, recognizes no dividing line between man and brute.” Thus, animals became the ideal subjects for experiments, especially for experiments researching stimulus and reaction relationships. The research of behaviorists was predominantly focused on learning and its application into everyday life. In essence, the entire functioning of organisms in the world was assumed to be a product of learning. Undoubtedly, behaviorists did not understand cognition (mind) as we understand it nowadays. The human cognition was viewed in simpler terms and in the same way the (cognitive) abilities of animals were viewed. In general, the cognitive abilities were just considered from the stimulus and reaction framework, as a set of responses to the environment based on learning. As Skinner (1953) describes it, behaviorists worked on the premise that it is not convenient to have all responses innate. Due to the ever-changing environment, it is much more beneficial for the survival of an organism to possess mechanisms which enable learning of new responses for both humans and animals. Furthermore, behaviorists were not fond of the complexity of reactions of human subjects during the experiments. For the experiment itself, the most convenient way was to eliminate all the other variables. Acknowledging that animals have the same mechanisms of learning, but of lower complexity compared to humans, it seemed less demanding to control for confounding variables in non-human species. The behaviorists readily and without hesitation generalized all the findings gained through experimentation on animal subjects to humans. For instance, Skinner (1953) conducting experiments on pigeons states: "…the resistance to extinction generated by intermittent reinforcement may be much greater than if the same number of reinforcements are given for consecutive responses. Thus, if we only occasionally reinforce a child for good behavior, the behavior survives after we discontinue reinforcement much longer than if we had reinforced every instance up to the same total number of reinforcements." In the experiments conducted by behaviorists, there was no emphasis put on the ecological conditions in which certain species evolved. This fact most likely negatively influenced the results of experiments and their generalizability to humans.

Cognitivism, the next paradigm that gained popularity in the research on the mind, came with the idea to try and open the so-called "black box". Primarily, the main goal was to uncover as much as possible regarding the human mind. Cognitivism fully accepted the idea of Darwinian organic evolution. Therefore, a part of the cognitive psychology research was focused on examining cognitive abilities in animal subjects. Some domains researched by cognitive psychology, such as memory, attention, perception, thinking, insight, even beginnings of consciousness research were also examined in animals. The main purpose of the animal research was to examine how the whole cognitive machinery works in less complex species. However, as in the case of behaviorists, the main goal of the research on animals was to more thoroughly understand human cognitive abilities. Animals were just a means to an end for exploring cognition. At that time, even when animals were considered highly intelligent and evolutionary intertwined with humans, limited concern was given to their well-being and cognitive psychologists carried out plenty of invasive experiments.

1.3 Biocentric view on the research of cognition

Subsequently, a lot of research areas emerged with the focus on explaining cognitive abilities of animals and humans. Majority of them are to a great extent similar in their objectives, but still minor differences hinder their unification (Shettleworth, 2009, Shettleworth, 2010). Cognitive psychology is considered to stand at the beginning of evolutionary (or comparative) psychology. The goal of evolutionary psychology is to apply evolutionary thinking into psychology. Essentially, it attempts to find certain precursors of human cognitive abilities in other species. It suggests that human cognition is the most developed one and should be considered as a reference point. Therefore, cognitive abilities of other species (predominantly those closely related to humans) and their experimental performance on various tasks are compared to the abilities of humans (Tooby & Cosmides, 2005).

The field of animal (or comparative) cognition also emerged from cognitive psychology. However, it evolved in a different direction in comparison with evolutionary psychology. This field is primarily focused on the animal cognition per se and advocates for a biocentric approach to cognition (Kamil, 1987). It holds that by employing a comparative approach, it is possible to infer about the evolution of cognition (Brauer et al., 2020). This field highlights the ecological approach to cognition and criticizes the anthropocentric view for studying the animal cognition. The animal cognition researchers do not deny that human cognition is unique. Rather, it is proposed that cognition of other species is unique as well in their species-specific way. For that reason, cognition of humans should not be assumed as a reference point in the cognition research (Brauer et al., 2020).

The approach of cognitive biology to researching cognition resembles significantly the approach of animal cognition research. The difference seems to be in their origins. While the field of animal cognition has its roots in cognitive (experimental) psychology, the field of cognitive biology has its origins in biology. From the philosophical perspective, cognitive biology has much in common with the enactivist view on cognition. The key idea is to research cognition as such and not to solely focus on human cognition. In the view of cognitive biology, cognition is a biological phenomenon governed by the principles of evolution. Even the simplest organisms that interact with their environment are considered to be cognitive organisms.

1.4 Enactivism as an ecological approach to cognition

Enactivist approach to cognition evolved on the grounds of ideas of autopoiesis, embodied cognition and situated cognition. For enactivists, the term cognition itself gets another meaning compared to previously mentioned paradigms – behaviorism and cognitivism. Enactivism proposes the idea that all living systems are cognitive systems and that life as a process is a process of sense-making. Hence, cognition is not something that is only carried out in a brain, but something that requires the whole body and its interaction with the environment. Thus, enactivism refutes the computer metaphor of the brain proposed and widely preferred by cognitivists. Particularly, cognition does not even require formation of symbolic representations. This has far-reaching consequences on the overall requirements necessary for cognition – there is no need for an organism to possess a nervous system. From this enactivist view, cognition is grounded on the living body. In terms of enactive theory, this is understood as an autonomous system (Di Paolo and Thompson, 2014). As Di Paolo and Thompson (2014) suggest: "A key attribute of the living body is its individuation, the process by which it makes itself distinct from its immediate surroundings and that enables an observer to distinguish it as an identifiable entity." In the words of enactivists, this attribute is called a self-individuation. Furthermore, for the living autonomous system, it is necessary to be operationally closed and precarious. Di Paolo and Thompson (2014) further explain: "… a precarious, operationally closed system is inherently restless, and in order to sustain itself despite its intrinsic tendencies towards internal imbalance, it requires energy, matter, and relations with the outside world. Hence, the system is not only self-enabling, but also shows spontaneity in its interactions due to a constitutive need to constantly "buy time" against the negative tendencies of its own parts." Enactivism also puts a lot of emphasis on the environment which the specific organism interacts with and where its ancestors evolved. In the enactivist view, cognition becomes a process that is not unique to human beings. Organisms are viewed as great problem-solvers for those environments they evolved in. With certainty, we, as human beings are special in our unique ways; nevertheless, not as special as we for centuries used to believe.

1.5 Ephemeral task

The general principle of the Ephemeral reward task used in our study is as follows. An animal is presented with two options which contain the identical type and amount of reward. These two options are of distinctive color, shape, pattern or combination of more than one distinctive feature. In essence, there exists a specific cue that can be associated with each option. For an easier and quicker orientation, these two distinctive options are named. There is the permanent reward that can be chosen at any time, and an ephemeral reward which is removed, if not chosen first. That means that choosing the ephemeral reward first allows the choice of the permanent reward after, resulting in two rewards per trial. Choosing the permanent option first leads to the end of a trial and the gain of only one reward. Based on this outcome for the subject, one can also refer to the ephemeral option being the first choice as the optimal choice, and the permanent option being the first choice as the suboptimal choice. Therefore, in order to understand the task and in that way maximize the food intake, a subject first needs to associate the distinct choice with the specific outcome. And based on this association, if a subject wants to gain more rewards, it needs to learn that one of these outcomes is more beneficial in maximizing the food intake. The ephemeral reward task is limited to 100 trials. These 100 trials are divided in 10 sessions of 10 trials each.

From the human perspective, it might seem that the task is extremely simple. However, the task does not operate in a transparent fashion. It is necessary to keep in mind that it is the suboptimal (permanent) option that provides the reward every time. No matter what, the animal will always be rewarded when choosing the suboptimal option. On the other hand, the optimal (ephemeral) option provides its rewarding effect only when chosen first. To make things even more intriguing, the suboptimal option is always experienced as last before the termination of the trial. It simply means that when the trial is over and an animal leaves the testing compartment, the freshest association in its neural networks is the one that is linked to the last option experienced, which is always the suboptimal one. Thus, an animal needs to overcome initial urge that tells it to pick the option that is experienced always during the testing plus is experienced last at each trial.

1.5.1 History of the Ephemeral reward task

The task is inspired by the natural behavior of the species of Cleaner wrasse (*Labroides dimidiatus*). Cleaner wrasse is a small fish that leaves at reefs. Each cleaner wrasse resides at its station – the territory. It mainly feeds on parasites and mucus that reside on scales of bigger fish. For these bigger fish, it is beneficial to get rid of these parasites. Hence, they deliberately seek out cleaner wrasses to obtain the cleaning service. In terms of this feeding relationship, the bigger fish are usually called clients. For cleaner wrasse, there is oftentimes more than one client to service, resulting in the necessity to make a choice who should be prioritized. There are two main groups of clients. The first group consists of resident clients that permanently live at the reef. Resident clients are obtaining the cleaning service at the cleaning station of their dwelling-place. They do not swim between various cleaning stations. Hence, from the perspective of cleaner wrasse Resident clients can be considered as a permanent source of food. The second group of clients consists of fish that live in the open ocean and they visit reefs in order to obtain the cleaning service. These clients are also called "Choosy" clients because they can choose the cleaning station where they will get served. These Choosy clients do not like to wait, so if they do not obtain the cleaning service immediately, they will swim to another station. From the point of view of cleaner wrasse, Choosy clients are regarded as an ephemeral source of food. Based on this behavior of Choosy clients, cleaner wrasse as a species learned to serve Choosy clients first, so they maximize their food intake (Bshary, 2001). Moreover, when the Choosy client is satisfied with the cleaning service, it returns to this particular station. So, prioritizing the Choosy client over a Resident client is of great feeding benefit for cleaner wrasse. (Bshary, 2001).

Subsequently, based on these observations of cleaner wrasses in their natural habitat Bshary and Grutter (2002) came up with the laboratory design mimicking this natural behavior. In their experiment, a cleaner wrasse fish is placed into the aquarium. The aquarium is separated in 2/3 by the removable opaque wall into two parts. A fish stays in the smaller part which is regarded as a waiting compartment. After 60 seconds two plates are inserted into the testing compartment at an equal distance. The plates abstractly represent the Choosy client and the Resident client. To discriminate between these plates, they contain different patterns which are of different colors. After 10 seconds, the opaque wall is removed, and fish is free to choose the plate behind which it swims first. Here, the principle of Ephemeral reward task described above is observed. All the six subjects which participated in this study managed to understand the principle of this task within 100 trials, by reaching one of the learning criteria for a successful passing. More specifically, the first criterion for passing requires making ten out of ten or nine out of ten optimal choices in one session. Second criterion requires, making eight out of ten optimal choices in two consecutive sessions. And the final, third criterion requires making seven out of ten optimal choices in three consecutive sessions. Most of the subsequent Ephemeral reward task experiments conducted on other species constrained the limit for successful accomplishment of the task to 100 trials and employed the same learning criteria. These 100 trials are predominantly divided into 10 sessions of 10 trials.

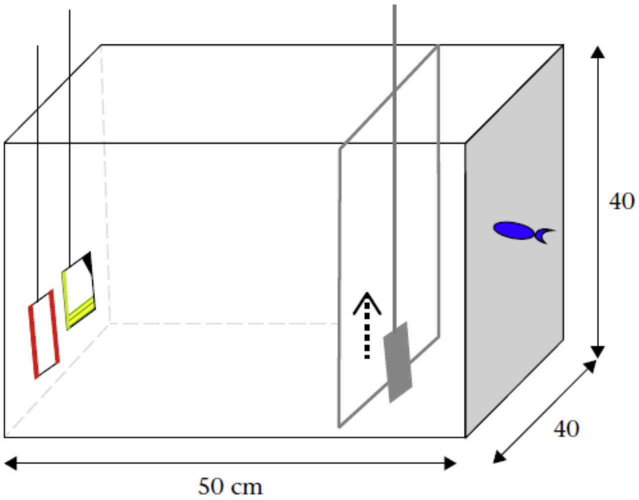


Figure 1: The setting utilized for cleaner wrasse (Bshary & Grutter, 2012).

The setting used in the very first Ephemeral reward task experiment on cleaner wrasse. The fish waits in the waiting compartment until the sliding plate is taken out and swims behind one of the two distinctively colored and patterned plates. If the subject chooses the ephemeral option first (pre-set by the experimenter which of the two plates is regarded as the ephemeral one) it is also allowed to swim to the permanent option and take the reward from there and the trial is over. However, in case the subject chooses the permanent option first, the second (ephemeral) option disappears from the aquarium and the trial is over. The Ephemeral reward task is limited to 100 trials divided into 10 sessions of 10 trials.

In their study, Salwiczek et al. (2012) set out to explore whether this ability to differentiate between two plates and understand the principle of the task is inherited and thus innate for the cleaner wrasse as a species or whether it depends on individual experience. They conducted the experiment with two groups of cleaner wrasse fish. First group consisted of six adult individuals and the second group of seven juvenile individuals. All the six subjects from the first group were able to successfully fulfill the task in 100 trials. On the other hand, only one subject from the second group managed to do so. According to the authors, this finding most likely hints toward the major role of individual experience on the ability to solve the task. In the field study conducted by Bshary (2011), the juvenile cleaner wrasses did not have as many visiting clients as adult ones, hence they were only rarely forced to discriminate between the Choosy and Resident clients.

Salwiczek et al. (2012) also explored whether nonhuman primates are capable of understanding the Ephemeral reward task. They conducted experiments on four chimpanzees (*Pan troglodytes*), four orangutans (*Pongo abelii*) and eight capuchins (*Sapajus apella*). The subjects were presented with a simple setting with visible rewards placed on distinctively colored plates. Despite the initial predictions, most primates were unable to understand the task within the given limit of 100 trials. Majority of them developed a side bias. Various hypotheses attempting to explain the reason why primates with their complex brains failed at this task emerged. The soundest hypotheses focused on the issue of ecological validity (Pretot et al. 2016) and ability to control initial impulses (Zentall et al. 2016a, 2016b).

1.5.2 Ecological Approach to Ephemeral task

When conducting comparative experiments, where performance of different species is compared on one specific task, it is always a challenge to say what the exact reasons are when one species outperforms another. It does not only have to be a difference in the cognitive abilities which enables one species to succeed while others fail. The other factors that may play a role can be of various nature. When attempting to understand the reasons of inability to successfully accomplish the task it is necessary to keep in mind whether the particular animal is a member of a species that live in social groups, if they form hierarchies, if they are good cooperators and such. These are often referred to as social factors. Moreover, there might be anatomical or physiological hindrances that do not allow species to perform optimally on the given task. Also, it is important to pay attention to the environment the species evolved in and live in, referred to as ecological factors. There are many species-specific adjustments to their native environment which can lead to the animal assigning importance to different environmental cues as may be necessary for succeeding in the abstract laboratory task. Hence, when the perception of a species is attuned to different cues than to those that are required by the task at hand, it might be next to impossible to accomplish the task or it might require a prolonged period of learning. Ecological approach to cognition basically emphasizes these ecological factors in order to better understand performance and abilities of various species.

Pretot et al (2016) carried out an experiment of Ephemeral reward task on capuchins (*Sapajus apella*). In this version of the task, the authors paid closer attention to the ecological factors of capuchins. Their motivation was to explore whether the inability of capuchins to initially understand the principle of the task (Salwiczek et al., 2012), was the result of insufficient cognitive abilities or certain ecological factors stepped into the process. The authors considered some important factors that they planned to adjust. Firstly, in primates´ environment, the appearance of food itself has the essential effect on grabbing the attention of the individual and can serve as a relevant cue for making a choice. Since capuchins use the visual cues of the food item itself to decide on an action in the feeding context, the ephemeral and the permanent reward should be distinguishable themselves, and not just the placeholder where the reward is placed upon. Based on this idea, in experiment 1, researchers employed the design with two distinctively colored pieces of food reward (using a food color, one piece was colored black and the other was colored pink) placed on the identical plates. Secondly, previous studies revealed (e.g. Murray et al. 2005, Boysen et al., 1996, Boysen et al., 1999), that direct visibility of the food rewards impose a negative effect on the decision-making abilities of primates. For this reason, the idea of experiment 2 was to limit this negative effect by covering the food rewards with distinctively colored cups. The results showed that adjusting the methodology while taking the ecology and limitations of the species into account, allowed capuchins to understand the underlying principle of the task. In the first experiment, nine out of nine subjects accomplished the task within the criterion of 100 trials. Regarding the second experiment, also nine out of nine subjects managed to accomplish the task (Pretot et al., 2016).

Pigeons (*Columba livia)* and rats *(Rattus norvegicus)* became other species that participated in the Ephemeral reward task (for pigeons see Zental et al., 2016, Zentall et al., 2017a, for rats see Zentall et al., 2017b). Both species failed to understand the principle of the task. Majority of pigeons even developed the preference for the suboptimal choice. Subsequently, the automated setting of the task was introduced to eliminate the possible negative effect of presence of the experimenter. This adjustment did not help_rats and pigeons solve the task. Zentall et al. (2017a, 2017b) came up with the idea that self-control might be a mechanism that plays an essential role in successful accomplishment of the task. Based on the experiment on delayed discounting (Rachlin & Green, 1972), they introduced the setting of the task in which an animal made a so-called prior commitment. The principle of prior commitment lays in the idea that after making the initial choice, the animal must wait 20 seconds and only then is it presented with the food reward. To put it more precisely, subjects made their choices on the touchscreen by touching with the beak (Zentall, 2017a) or the muzzle (Zentall et al., 2017b). In case the subject opted for the ephemeral option first, after the waiting period of 20 seconds, it was allowed to obtain the food reward associated with it. After taking this reward, it was immediately allowed to make the second choice and thus obtain the reward from the permanent option as well and the trial was over. In case the subject opted for the permanent option first, after the waiting period of 20 seconds, it was allowed to obtain the food reward associated with the permanent option and the trial was over. Both, rats and pigeons learned to reliably choose the ephemeral reward first in this setting where prior commitment was required. However, it is necessary to mention that they were tested in many more trials. They grasped the underlying idea of the task within 300 trials.

1.5.3 African Gray parrot

Pepperberg and Hartsfield (2014) conducted the experiment using ephemeral reward task with the African Gray parrot (*Psittacus erithacus*). The experimental setting resembled very much the original setting used by Salwiczek et al (2012) when conducting the experiment on primates. In short, it consisted of two distinctive plates that the reward was directly placed on. Hence it was a simple setting with visible rewards and without any ecological adjustments. The study was conducted on 3 subjects and all of them were able to understand the principle of the task within the criterion of 100 trials. As pointed out by Zentall et al. (2017b), African Gray parrots are not very impulsive in general, which might have helped them in solving the task. However, he also emphasized the fact that all three individuals underwent extensive prior training either in interspecies communication or referential communication which supposedly had even greater effect on the reduction of impulsivity. Moreover, one of the birds was trained to wait 15 minutes in order to obtain the more desirable reward than was initially given. Hence, the results of this experiment should be considered with caution.

1.6 Quantity discrimination

From the perspective of the Ephemeral reward task, it is immensely important that an animal is capable of discriminating quantities. Since the principle of the Ephemeral reward task is based on the motivation of a subject to increase the amount of obtained reward, this would be almost impossible for a subject that belongs to a species that is not capable of discriminating quantities. Examining the numerical abilities of non-human animals has long been of interest for researchers in the field of animal cognition (Shettleworth, 2010).

Fundamental in this aspect of numerical cognition seems to be the ability to discriminate quantity. Also, quantity discrimination is considered to be the precursor of symbolic counting (Gallistel and Gelman, 1992; Carey, 2001). Most of this research focused on experimental designs where extensive training was required to assess these numerical capacities of animals (Hauser et al., 2000). In the recent period, research focused on examination of spontaneous discrimination of different quantities of items. There were studies carried out on various species ranging from humans (infants, Barth et al. 2003; adults, Feigenson et al. 2002) and primates (e.g., Beran & Beran 2004; Hanus and Call 2007; Hauser et al. 2000), lions (McComb et al., 1994), dogs (Ward & Smuts, 2007) horses (Uller & Lewis, 2009); dolphins (Jaakkola et al., 2005), sea lions (Abramson et al., 2011); salamanders (Uller et al., 2003). For a long time, the research in quantity discrimination of birds was scarce. However, in recent period studies on New Zealand robins (Garland et.al, 2012), jungle crows (Bogale et al. 2014), African Gray parrots (Ain et al., 2009), and Clark´s nutcracker (Tornick et al., 2015) appeared. For these purposes, the design with simultaneously presented rewards is employed. An animal is presented with two different quantities of items at the same time and is supposed to make a response (picking one or another). The term spontaneous indicates that no previous training was conducted (Bogale et al. 2014, Hauser et al., 2000).

The research conducted in the area of quantity discrimination indicates towards at least two major systems that might be utilized for representing quantities. According to Feigenson et al. (2004), the first system, called the Object file model accounts for quantity discrimination abilities related only to small sets of items. The principle of functioning of this system is based on perception of items which are stored in visual working memory in distinct object files. Since visual working memory is limited to a small number of items in humans as well as in animals (Baddeley, 2010, Elmore et al. 2011), the object file model is constrained by these limitations. The object file model provides good explanation for discrimination abilities of small sets. Studies of the object file model suggest this small set of items is restricted to four in adult humans (Feigenson et al. 2002), and three in infants (Barth et al. 2003), while non-human primates like rhesus monkeys also can store four items in their visual memory (Hauser et al. 2000; Wood et al. 2008).

The second system, named the Analog magnitude model appears to be used for quantity discrimination of larger sets of items. This model is considered to work on the principle of Weber´s law (Tornick et al., 2015), which takes into account the ratio between two quantities. Thus, it should be less demanding to differentiate between two sets of items if the ratio between the quantities of items in each set is low. Hence it is easier to discriminate two from three (2/3=0.66) than eight from nine (8/9=0.88) despite both sets of numbers having an identical absolute difference of 1 (Tornick et al. 2015).

The ability to discriminate different quantities provides specific species with improved fitness. The selection pressures for this ability depend mainly on ecological factors and enable the species in question to solve a variety of problems. In birds, there are many benefits of quantity discrimination. For instance, the ability to discriminate quantities helps American coots and wood ducks to prevent from brood parasitism (Lyon et al., 2003; Odell and Eadie, 2010). For caching or scatter-hoarding birds, this ability for discriminating among smaller and larger quantities of their caches allows for more efficient food retrieval (Garland et.al, 2011, Hunt et al.,2008).

1.7 Research questions, hypotheses, predictions

Our first and main research question is whether kea parrots are capable of understanding the ephemeral reward task. The second research question, if kea can discriminate between two pieces of reward and one piece of reward. In actuality, this second question is an immensely important precondition for our first research question because the two experimental tasks we plan to employ, if both chosen optimally, lead to the final outcome of increasing food intake of the subject. The major difference is in the principle of the task. While in quantity discrimination task the animal chooses between options, from which one option contains two rewards, in the ephemeral reward task, each of the options always contains only one piece of reward. In this case, the important outcome is which option is chosen first. Therefore, especially in the setting with visible rewards, if kea do not discriminate between two and one rewards, without any other restrictions, then the question remains if they would be motivated to choose the ephemeral reward to increase their trial output from one to two rewards.

Especially, in the two versus one quantity discrimination task with visible rewards we predict that kea should be motivated to maximize their food intake.

By having the data from these two experimental tasks, we are curious to explore in our third research question which one of the two tasks - the ephemeral reward task or two versus one quantity discrimination task - is more difficult to comprehend for kea. Since, each experimental task will be carried out in two different settings, our fourth research question is aimed to explore, which of the two settings – the setting with visible rewards or the setting with non-visible rewards - will allow more subjects, or the same number of subjects but more quickly, to reach the criterion within the task limit.

Our hypotheses are formulated as follows:

H1: The differences between the ephemeral reward task and the two versus one quantity discrimination task will affect the performance of kea.

H2: The differences between the setting with visible rewards and the setting with non-visible rewards will have an effect on performance of kea in both tasks.

We predict that two versus one quantity discrimination task is easier in its nature and hence more individuals will reach the criterion in this task, independent of the setup. Furthermore, in line with previous research (Pretot et al., 2016, Zentall et al., 2017a, 2017b), we predict that more individuals will reach the criterion in the setting with non-visible rewards in both tasks. However, due to the still uncertain nature of the prevailing theories, we alternatively predict, that the kea might have greater impulse control than the rats and pigeons, in which case the direct presentation of the rewards may allow more subjects to reach the criteria.

2 Methods

In the beginning of the practical part of the thesis, our subjects and their housing conditions are introduced. The following part closely describes the two experimental tasks we will employ in our research study – the Ephemeral reward task and the Two versus one quantity discrimination task. Both of these two tasks will be presented to our subjects in two different settings, hence the setting with visible rewards as well as the setting with non-visible rewards (T-maze setting) are described next. Finally, the detailed procedure of experiments is described.

2.1 Ethical Note

The testing was assessed and approved by the institutional ethics committee in accordance with the Good Scientific Practice guidelines and national legislations. All subjects that participated in our experiments are housed in accordance with the Austrian Federal Act on the Protection of Animals (Animal Protection ActdTSchG, BGBl. I Nr.118/2004). Moreover, as this study was strictly noninvasive and based on behavioral observations, all experiments were classified as non-animal experiments in accordance with the Austrian Animal Experiments Act (x 2, Federal Law Gazette No. 501/1989). No individual was ever forced into testing. In case that an animal refused to continue in testing during the experiment, the session was terminated.

2.2 Subjects

Kea (*Nestor notabilis*) are an endemic parrot that resides at the South Island of New Zealand. The name kea comes from Maori language and is used for both singular and plural form. In actuality, the name kea is supposed to be onomatopoeic – kea sounded to the Maori like they are calling “keeaah”. Kea can be easily recognized for its olive-green color with the orange underwings and rump with the large and slender bill (Diamond & Bond, 1999). The average length of the individual is 46 cm, the weight for a male varies from 900g to 1100g and for a female from 700g to 900g. Females are generally 20 % smaller. Juveniles are recognizable due to yellow ceres and eyelids which fade to gray with the progressing age. (Kemp, 2013). Kea are omnivorous, feeding on a wide range of plant and animal matter.

They forage in trees (shoots, fruits, leaves, seeds), dig in the ground (larvae) or scavenge on carcasses (sheep, chamois, deer). In the past, with the spread of sheep in New Zealand, some individuals learned to perch on the back of the sheep, dig through the skin and muscle with their sharp bills and feed on the fat of sheep (mainly feeding on the fat around kidneys which often resulted in the death of a sheep). Although, this behavior was quite rare, kea were being hunted because of it for over a hundred years. These days, kea are an endangered species and are protected by law. Generally, kea are considered to be highly intelligent and in their cognitive abilities are often being compared to primates. It is assumed that it is their curiosity and complex social interactions that stand behind their intelligence. Specifically, during the juvenile period, juveniles are tolerated by non-related adults which brings the ease to learning of complex foraging strategies and behaviors. Moreover, the juvenile period is extended compared to other parrots (Diamond & Bond, 1999). Hence, kea parrots and their cognitive abilities became popular adepts for animal cognition research.

2.2.1 Housing

The entire group of kea consisted of 27 individuals of various ages. For our experiment we employed seventeen individuals. They reside in an outdoor aviary with the size of 52x10x6m. The ground of the aviary is covered with a sand substrate. Generally, the birds are kept as one group and the entire area of aviary is accessible to all the birds except for the breeding time when the breeding pairs are separated from the rest of the group in the Refugium Occidentis or Refugium Aurorae (see figure 4). The area of the aviary can be divided into nine separate compartments. This is easily done by sliding the door made of wire mesh. The aviary has two experimental compartments (Porticula Occidentis and Porticula Aurorae) which in times when no testing is carried out are freely accessible. These two experimental compartments can be separated from the rest of the aviary space not only by the wire-mesh door but also by the system of opaque sliding doors. Thanks to this, it is impossible for the rest of the birds to see what is going on in the experimental compartment and hence it hinders the possibility of learning the task by watching another bird while performing the task. Furthermore, each of the two experimental compartments can be divided into the waiting compartments (Porticula Spectans and Porticula Expectatio) and the setup compartments (Porticula Tabula and Porticula Res). This is immensely convenient when one experimental session consists of multiple trials. The sliding of the wire-mesh door and the entrance of the bird signals the beginning of the trial and when the bird leaves the testing compartment and the wire-mesh door are closed, it is a signal of the trial termination. The central living area referred to as Forum consists of Aula Pinifer, Hortus, Aula Exoticus. Mainly in this part of the aviary, various environmental enrichments are placed. They include tree branches, small trees to a pile of stones, two ponds filled with water and wooden sheds.

The entire experiment was conducted in Porticula Aurorae. The birds are fed three times a day with a mixture of vegetables, fruits, seeds and animal protein (worms, eggs, cheese, minced meat) depending on the individual diet and season. They are never food deprived and water is available ad libitum.

Figure 2:The aviary at Haidlhof

The above look on the aviary at Haidlhof research station where the kea reside.

Figure 3:Inside of the aviary

The look into the aviary. Plenty of environmental enrichments are visible in the picture. It is possible to divide the entire area of the aviary into smaller compartments by sliding the wire-mesh door system.

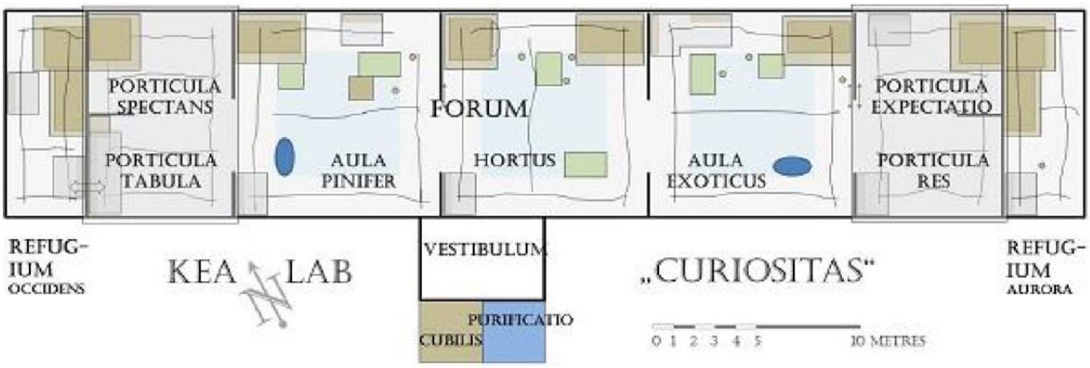


Figure 4:Schematic of aviary

Schematic of aviary with breeding compartments (Refugium Occidentis, Refugium Aurorae), testing compartments (Porticula Occidentis, Porticula Aurorae), and living compartments (Aula Pinifera, Hortus, Aula Exotica). Each of the testing compartments (10 x 6 m) can be further divided into waiting compartment (Porticula Spectans, Porticula Exspectationis) and setup compartment (Porticula Tabula, Porticula Rerum) using wire-mesh sliding doors. (Schwing et al., 2017).

Table 1:List of participating birds

The first column represents the name of the bird. The second column contains the information about the sex of an individual (M=male, F=female). The third column shows in which task an individual participated (ERT= Ephemeral Reward Task, 2vs1= Two versus One Quantity Discrimination Task). The fourth column indicates which color or pattern represented the optimal (ephemeral or containing two pieces of reward) choice (W= White color, B= Black color, T= T-shape pattern, O= O-shape pattern, - = the individual did not participate in the setting). The fifth column informs if a bird was reared by parents or by a human caretaker. The sixth column informs about the age of an individual.

Name	Sex	Task	Color/Pattern	Parent/hand reared	Year born
Anu	M	ERT	White/T	hand	2007
Coco	F	2vs1	-/T	hand	2007
Diana	F	2vs1	-/O	hand	2017
Fay	F	2vs1	Black/T	parent	2016
Jean-Luc	M	2vs1	White/T	hand	2015
John	M	2vs1	-/O	parent	1999
Kermit	M	2vs1	Black/T	hand	2004
Lilly	F	ERT	Black/O	hand	2007

Odo	M	ERT	White/O	parent	2015
Papu	F	ERT	-/T	hand	2013
Pancake	M	ERT	-/O	hand	2017
Paul	M	ERT	White/O	parent	2010
Pick	M	ERT	Black/T	hand	2004
Plume	F	2vs1	Black/O	hand	2007
Roku	M	2vs1	White/O	parent	2008
Skipper	M	2vs1	White/O	hand	2017
Sunny	F	ERT	Black/T	hand	2007
Willy	F	ERT	-/O	hand	2007

2.3 Set-up

In the following section, the reasons for the choice of distinctive features in the settings will be presented. Subsequently, the two experimental settings will be described – the setting with visible rewards and the setting with non-visible rewards.

2.3.1 The choice of distinctive features for our settings

Next paragraphs outline the reasons why both black and white color of the plates and O-shape and T-shape pattern painted on the plates were chosen as distinctive features in our experimental tasks.

2.3.1.1 White and Black color

We attempted to opt for as neutral colors as possible, because we have some anecdotal evidence that certain colors might be preferred. In an experiment which is not constrained by the amount of trials, it should not be a problem for kea to unlearn such preferences, but in our case, where the period for reaching the criterion is very short, we were careful with choosing of the colors. The fact that there was no previous research conducted exploring how kea perceive colors, we made our decision based on what is generally known about perception of colors in humans. Hence, the most neutral and contrasting colors for our purposes appeared to be black and white color (Sikl, 2013).

2.3.1.2 O-shape and T-shape pattern

In order to ensure that it is not the preference for black or white colored plate that may stand behind keas´ decisions of the plates, we decided to change the distinctive features of the plates. Still, we found it important to keep the plates in neutral colors, so both plates were of black color with white distinctive pattern on each of them. Since ´the current knowledge of the functioning of kea´s visual system has not been explored in great detail so far, we opted for these two patterns based on the research carried out in human visual system (e.g. Koch & Ullman, 1985, Sternberg, 2017). Also, we employed the findings of the research conducted in the area of attentional search – namely experiments dealing with feature search and conjunction search. The experimental evidence proposes that the constructing features of both patterns (letters), vary in many aspects. These experiments revealed that human subjects most readily (measuring reaction times) discriminate between these two patterns (Koch & Ullman, 1985; Itti & Koch, 2000).

2.3.2 Apparatus with visible rewards

A simple apparatus made of wooden plank of size 100x60 cm was used. It is placed on the sandy ground. In the bottom left-side corner and bottom right-side corner, thin wooden moldings are attached which form the space for small distinctively colored wooden plates (size of 15x15 cm). Thanks to this mechanism it is easy to manipulate with the plates, especially when switching their position for randomization of the color assignment. In the cases when the apparatus was used for Ephemeral reward task, one plate was colored white and the other plate was colored black. In the cases when the apparatus was employed in the two versus one quantity discrimination task, the removable plates were both of black color with two distinctive patterns (in our case letters) painted on it. One plate contains T and the other contains O. In both tasks, the reward is directly placed on these plates. The important factor is that the distance between the two plates is more than 50 cm (which is one body length of kea). This has two main reasons – Firstly, it brings a certain time delay before the bird gets the second reward if it chooses optimally (in case of ephemeral reward task). Secondly, if a suboptimal option was chosen, it is easier for the experimenter to remove the second plate in time before the subject approaches it, in order to manifest that the optimal (ephemeral) option disappears. In the ephemeral reward task, for one half of the birds the black colored plate stood for ephemeral option and the white one was considered being a permanent option. The other half of the birds had the conditions reversed, which means that white colored plate was representing ephemeral choice and the black one represented permanent choice. In the two versus one quantity discrimination task, the T-shape-patterned plate contained two pieces of reward and the plate with O-shape pattern on it contained one piece of reward for one half of the tested subjects. For the other half of the birds, the conditions were reversed, so the plate with the O-shape pattern had on it two pieces of reward and the plate with the T-shape pattern had on it one piece of reward.

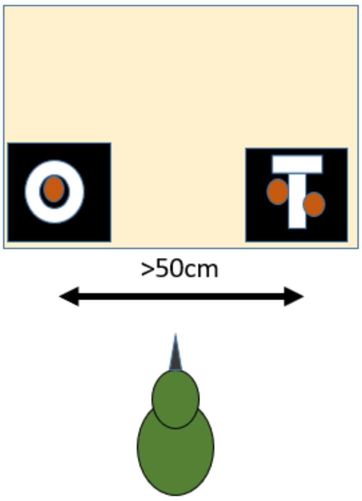


Figure 6: Sketch of the setting

Figure 5: Actual picture of the setting

The sketch and the actual picture of the setting with visible rewards utilized for the two versus one quantity discrimination task. The distinctiveness of plates is attained by painting a different pattern on each plate.

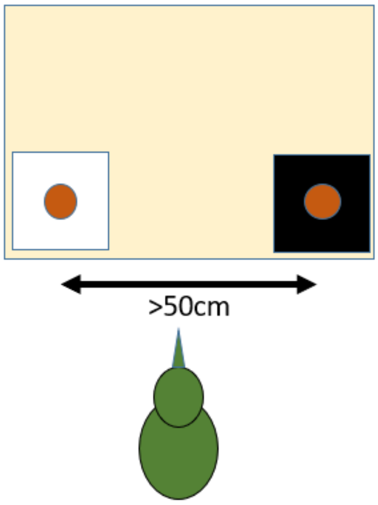


Figure 8:Sketch of the setting II.

Figure 7: Actual picture of the setting II.

The sketch and the actual picture of the simple setting with visible rewards utilized for the Ephemeral reward task. In the bottom corners, there are squared distinctively colored (black or white) plates with one piece of reward on each of them.

2.3.3 Apparatus with non-visible rewards (T-maze shape)

This apparatus was created in order to find out whether not directly seeing the reward will have any beneficial effect on the performance of our subjects. By designing the T-maze setting, we attempted to fulfill two main goals. Firstly, based on the studies of Zentall et al. (2017a, 2017b) and Pretot et al. (2016a, 2016b) introducing certain hindrance in direct perception of the food reward or introducing a time delay may help subjects to overcome the initial urge to automatically choose a reward of either option caused simply by the sudden perception of a food reward. It is suggested that the reason why not seeing the rewards has a beneficial effect is that the entire cognitive capacity of an animal is not overwhelmed by mere perception of the reward. Thanks to this, an individual can focus on other environmental cues that are essential in order to solve this task. Secondly, we assumed that the T-maze setting is in its underlying principles the most similar to the setting used by Bshary and Grutter (2002) which they employed in their initial experiment on cleaner wrasse fish. We perceived the resemblance mainly in the fact that cleaner wrasse had to swim behind the small plate in order to find the reward, which seemed to be the same type of action as walking of kea behind the wall.

T-maze shape apparatus looks from the point of view of a subject like a wall of size 100x60 cm. From behind, it is divided into two compartments with another wall-like structure. In the bottom corners of the front wall, there are attached thin wooden moldings which form the space for two small squared wooden plates (size of 15x15 cm). These squared plates are easily removable which allow for their manipulation according to the randomization plan. As in the previous setting with visible rewards, in this setting we also used the same types of distinctive features that are supposed to be associated with the choice. In the cases when this T-maze setting was used for the ephemeral reward task, both plates were colored black with two distinctive patterns on them. One of the plates had the O-shape painted on it and the other one had the T-shape painted on it. If it was utilized for the two versus one quantity discrimination task, two plates were of distinctive colors. One plate was colored white and the other was colored black. The subject needed to choose one side to go first. Behind the wall, the subject would see a small wooden plate of natural color. In case of the Ephemeral reward task, there is always one piece of reward placed on it. In case of the two versus one quantity discrimination task, subject can see the plate that has on it either one piece of reward or two pieces of reward. Regarding the color or pattern of the plate that will represent the optimal option for the specific animal we proceeded as follows. In the ephemeral reward task, for one half of the birds the T-shape pattern painted on the plate stood for the optimal (ephemeral) option and the O-shaped-pattern one was considered as representing the suboptimal (permanent) option. The other half of the birds had the conditions reversed, which means that O-shaped pattern on the plate was representing the optimal (ephemeral) option and the plate with T-shape on it stood for suboptimal (permanent) choice. In the two versus one quantity discrimination task, the black-colored plate was associated with two pieces of reward and the plate colored of white was associated with one piece of reward for one half of the tested subjects. For the other half of the birds, the conditions were reversed, so the plate colored white stood for two pieces of reward and the plate colored black stood for one piece of reward.

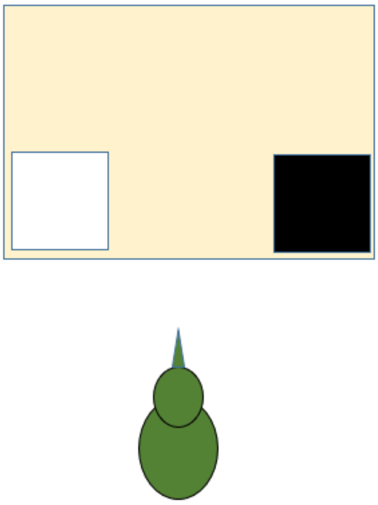


Figure 9: Sketch of the T-maze - front view

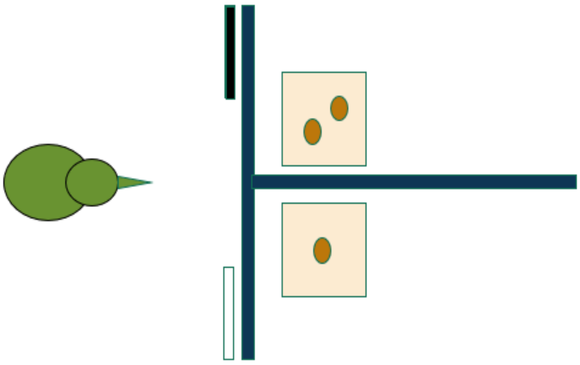
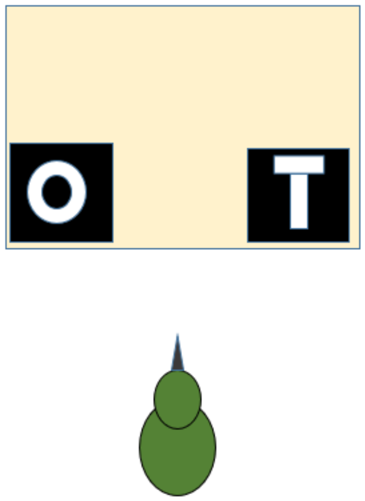


Figure 10:Sketch of the T-maze - above view

The sketch of the T-maze apparatus used for the setting with non-visible rewards in the Two versus one quantity discrimination task. From the perspective of bird (*Figure 9*) an apparatus looks like the big wall, with two distinctive plates (colored black or white) attached to it in the bottom corners. The bird is supposed to learn to associate one of the colors with the number of food rewards it contains. From the above view *(Figure 10),* it is visible how the pieces of reward are distributed. In the picture case, if a subject is motivated to maximize its food intake, it has to learn that black colored plate represents two pieces of reward and subsequently a subject should walk behind the black corner and take the pieces of reward.

Figure 11: Actual photo of the T-maze

The actual photo of the T-maze apparatus used in the Two versus one quantity discrimination task.



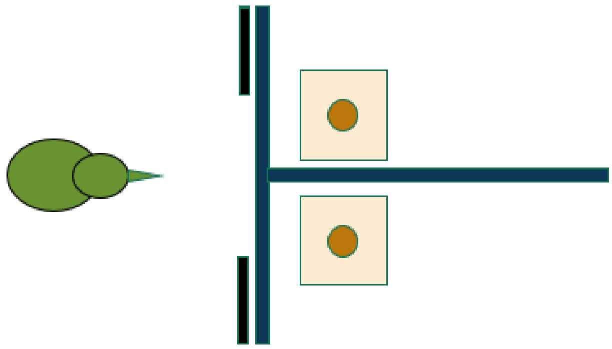


Figure 13: Sketch of the T-maze - front view II.

Figure 12: Sketch of the T-maze - above view II.

The sketch of the T-maze apparatus used for the setting with non-visible rewards in the Ephemeral reward task. From the perspective of the bird (*Figure 12*) an apparatus looks like a big wall with two distinctive plates (T-shape or O-shape painted on the black plate) attached to it in the bottom corners. The bird is supposed to learn that each plate stands for one piece of reward. As the next step, it needs to learn that choosing one of the sides first, allows it to obtain the reward also from the second side. From the above view *(Figure 13)*, it is visible how the pieces of reward are distributed. In the picture case, if a subject is motivated to maximize its food intake, it has to learn that walking first behind the corner with the painted T-shape on the plate, allows it to get to the other side of the T-maze and obtain the second reward as well.

Figure 14: Actual photo of the T-maze II.

The actual photo of the T-maze apparatus used for the Ephemeral reward task.

2.4 General Information regarding the process of the experiment

Each session consisted of 10 trials. Each bird had the maximum possible amount of sessions equal to 10, which makes it 100 trials. This trial limitation of the task was set by the experiment of Bshary and Grutter (2002) in which cleaner wrasse fish learned the principle of the task in this amount of trials. Hence, for the comparison to other species and their ability to quickly learn the principle of the task, the Ephemeral reward task is constrained to the same amount of hundred trials. The criteria for evaluation of performance of the subjects followed the rules employed by Bshary and Grutter (2002) and Salwiczek et al. (2012) as closely as possible. That is, the subject was considered to having successfully met the criterion of the experiment when it made optimal (ephemeral) choices on a) 10/10 trials or 9/10 trials on one session, b) 8/10 trials on two consecutive sessions or c) 7/10 trials on three consecutive trials. Subjects were considered as unsuccessful in solving the task if they either developed an inclination to the permanent option (the one not offering maximal payoff) or basically did not develop any inclination in the amount of 100 trials. There was one other important aspect that was considered in case the bird fulfilled the criterion for passing the task on its very first session. If the bird should be considered as successful, it needed to experience the outcomes of both options. In practice, regarding the bird as successful in solving the task, it had to opt for the suboptimal option at least once to avoid the possibility that it was biased for a certain color or pattern by chance. Hence, making ten optimal options out of ten possibilities on the first session did not fulfill the criterion for accomplishing the task (proposed by Pretot et al., 2016a). Furthermore, in case the bird partially fulfilled the condition for passing the task, which meant that on the ninth or tenth session it managed to make seven or eight optimal choices, it was granted the opportunity of the next session to prove if it understood the task or not (Pretot et al., 2016a).

The same learning criterion for passing the task was applied to the quantity discrimination task. Two rewards on one plate were considered as the optimal choice and one reward on the plate was considered as the suboptimal choice.

All the trials were recorded on a camera filming the side view. If the apparatus with non-visible rewards was used, a second camera was used to record events from the other side. As a reward, we used a highly preferred treat by kea – a piece of peanut. Since, the goal of the reward is to motivate an animal to participate in the experiment and not to get satiated, we used 1/8 of a peanut. This amount proved to be an adequate motivating portion in previous experiments. The reward was always placed in the middle of the colored plate. In the setting with visible rewards, close attention was paid to making sure that the pieces of reward were of the same relative size, so the subject would not take the difference in size of the reward as a cue. The testing session was over when the amount of ten trials was fulfilled. Effort was also made to ensure that the subjects had fresh water nearby so they could refresh themselves after eating a dry piece of peanut. We also had to ensure that the sides of the small squared plates kept randomly changing. This was done to avoid the birds developing a side bias as much as possible. For this reason, we made a semi-randomized schedule with two following rules. The first rule was that each option was presented on each side an equal number of times. The second rule was that the small plate of either color or pattern could not occur at the same side for more than three consecutive trials. Regarding the necessity to keep the track of accomplished performance, every time the trial was over (subject left the testing compartment), the experimenter noted down the performance of the bird in question. Plus, the experimenter changed the position of squared colored plates if it was required by the randomization plan and set the pieces of a reward on their correct place.

2.4.1 Individual pre-training

Since neither the setting of the Ephemeral reward task nor the quantity discrimination task required any special experience with manipulation of certain objects or anything that animals would have to learn anew, there was no need of pre-training. The kea have vast previous experience with testing and thanks to their curious nature, it was relatively easy to lure them into the testing compartment.

2.4.2 First experimental period

The first experimental period ran from March 4th, 2020 until April 6th, 2020. All sessions were conducted between 09:00 and 12:00 or between 14:00 and 16:00. Each bird went through only one testing session once per day (with one exception due to time constraints, Anu was tested at his 9th and 10th session on one day, once in the morning and once in the afternoon).

During the first experimental period, we conducted the ephemeral reward task in the setting with visible rewards and the two versus one quantity discrimination task employing the setting with non-visible rewards. The number of subjects participating in the ephemeral task was six kea parrots, four males and two females. In this experiment, we replicated the setting used by Salwiczek et al. (2012) utilized for the part of the experiment with primates. In the quantity discrimination task, six different kea parrots, four males and two females, participated in the experiment. The experiments were carried out according to the procedure that will be described in the section Procedure.

2.4.3 Second experimental period

Experiment two was conducted between June 22, 2020 and July 9, 2020. In almost all cases the birds were tested once per day. However, due to time constraints and possibility of the Covid-19 quarantine restrictions, there were a few exceptions. Since during this period of year, it was possible to test also in the evenings (from 16:30 to 19:00), we used the scheme when the bird was tested early in the morning of the particular day and then was tested in the evening. Hence, there was at least a gap of seven hours between the two testing sessions. Kermit and Jean-Luc were tested on their second and third session in this manner. Then Pancake was tested on his third and fourth session according to this scheme. Willy was tested on her fifth and sixth session on the same day. And in the end, Coco was granted the eleventh session on the same day as her tenth session was carried out.

During the second experimental period we conducted the ephemeral reward task with non-visible rewards setting (T-maze setting) and the two versus one quantity discrimination task in the setting with visible rewards. There were nine subjects, five males and four females, participating in the ephemeral reward task. In the quantity discrimination task, nine subjects, five males and four females, participated as well. However, after the first session, John refused to participate anymore and hence we ended up with eight participants altogether in this task.

2.5 Procedure

The following sections present the exact procedure of the four experiments that we carried out. Namely, the Ephemeral reward task utilizing the setting with visible rewards, the Ephemeral reward task utilizing the setting with non-visible rewards, the Two versus one quantity discrimination task utilizing the setting with visible rewards and the Two versus one quantity discrimination task utilizing the setting with non-visible rewards are described in detail.

2.5.1 Ephemeral reward task: setting with visible rewards

The apparatus was placed approximately one meter from the entrance to the set-up compartment. When the wire-mesh door was open the bird entered the set-up compartment from the waiting compartment and walked towards the apparatus (Figure 15).

Figure 15: Entrance into the set-up compartment

The bird was expected to choose one of the two distinctively colored squared plates. As the principle of Ephemeral reward task goes, if the bird took the reward from the ephemeral reward plate (optimal choice) first (black plate, in the case of Figure 16),

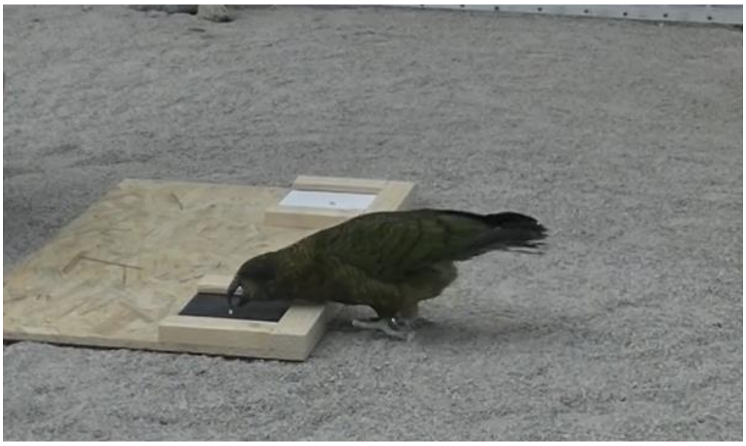


Figure 16: Subject choosing the optimal option

it was allowed to take the reward from the permanent plate (white plate, in the case of Figure 17) as well and the trial was over.

Figure 17:Subject allowed to take the second reward as well.

In case the bird took the reward from the permanent plate (suboptimal choice) first (Figure 18),

Figure 18: Subject choosing the sub-optimal option first

the ephemeral plate was removed from the reach of the bird (Figure 19) and the trial was over.

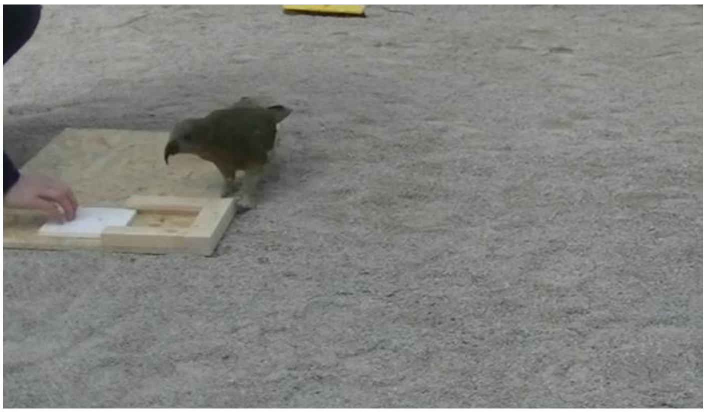


Figure 19: Removal of the optimal (ephemeral) plate.

A bird could eat the reward at the place or take it to its bill and feed on it while waiting on the next trial. The trial was over when the bird returned to the waiting compartment (Figure 20) and the wire-mesh door was closed.

Figure 20: Subject leaves the set-up compartment.

2.5.2 Ephemeral reward task: setting with non-visible rewards

The apparatus was placed around three meters far from the entrance to the set-up compartment. When the wire-mesh door was open the bird entered the set-up compartment from the waiting compartment and walked towards the apparatus (Figure 21).

Figure 21: Subject enters the set-up compartment.

The bird was expected to walk behind the wall-like structure. The choice, which side should be entered first, was supposed to be made on the basis of two different patterns painted on the small black plates. If the bird opted for the side with the optimal plate (ephemeral reward plate) on it first (in the case of Figure 22, O-shape pattern on the plate),

Figure 22: Subject choosing the ephemeral option first.

it was allowed to visit the other side, the side behind the T-shape pattern painted on the plate, of the apparatus as well and take the reward from there (Figure 23) and the trial was over.

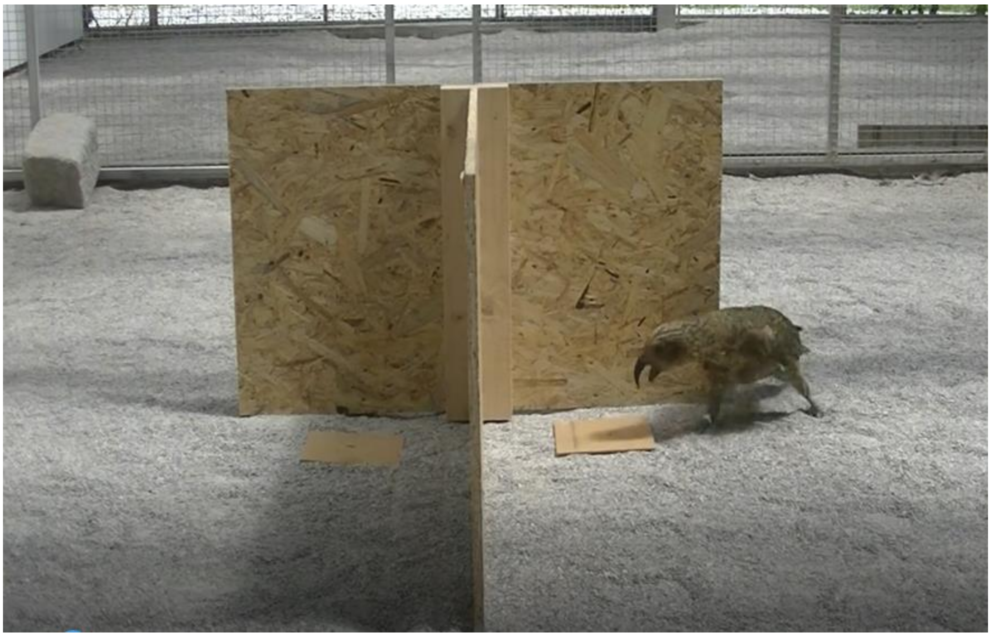


Figure 23: Subject taking the reward from the second side as well.

In case the bird walked behind the wall on the side with the plate representing the suboptimal option first,

Figure 24: Subject choosing the permanent option first.

after eating or picking the reward into the beak, the subject was sent out of the set-up compartment (Figure 25). The trial was over when the bird returned to the waiting compartment and the wire-mesh door was closed.

Figure 25:Subject walking out of the set-up compartment.

2.5.3 Two versus one quantity discrimination task: setting with visible rewards

The apparatus was placed approximately one meter from the entrance to the set-up compartment. When the wire-mesh door was open the bird entered the set-up compartment from the waiting compartment and walked towards the apparatus (Figure 26).

Figure 26: Subject entering the set-up compartment.

The bird was supposed to choose one of the two black colored plates that had a different shape painted on them and at the same time they had either two pieces of reward or one piece of reward on it (Figure 27).

Figure 27:Subject choosing one of the plates.

After making their choice, the subject ate or took the reward in its bill and left the set-up compartment and the trial was over (Figure 28).

Figure 28: Subject leaving the set-up compartment.

2.5.4 Two versus one quantity discrimination task: setting with non-visible rewards

The T-maze apparatus was placed approximately three meters from the entrance to the set-up compartment. When the wire-mesh door was open the bird entered the set-up compartment and walked towards the apparatus (Figure 29).

Figure 29: Subject entering the set-up compartment.

The bird chose one side to go to (Figure 30).

Figure 30: Subject choosing one side of the apparatus.

Behind the wall, it found either one piece of reward or two pieces of reward. The subject could eat the reward at the spot or take it in its bill before leaving (Figure 31).

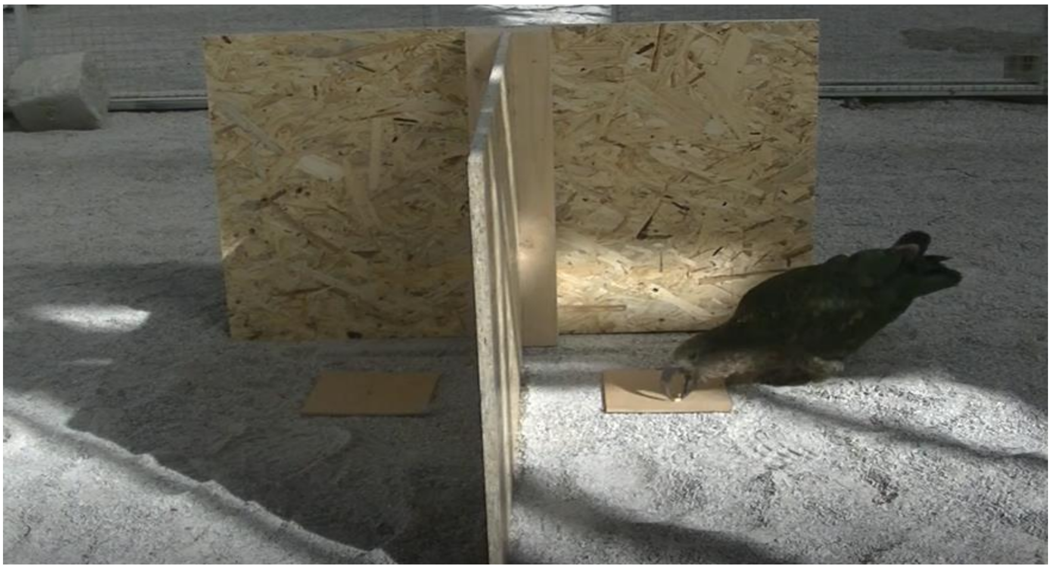


Figure 31: Subject obtaining the reward.

After obtaining the reward, the subject left the set-up compartment and the trial was over (Figure 32).

Figure 32: Subject leaving the set-up compartment.

3 Results

3.1 The Ephemeral reward task - setting with visible rewards

Three out of six birds reached criterion in the Ephemeral reward task when the setting with visible rewards was used. Lily technically reached the criterion on her very first trial – nine out of ten. However, to rule out other possible factors, she received one more session of testing. She performed in the similar fashion on her second session and reached nine out of ten again. Odo reached the criterion on his third session, picking ten optimal options out of ten. Finally, Pick managed to solve the task on his seventh trial making nine optimal choices within the session. Results are presented in the table 2.

Table 2: Results I.

The results representing actual performance of birds on particular testing sessions in the Ephemeral reward task in setting with visible rewards.

Session / Name	1	2	3	4	5	6	7	8	9	10
Odo	7	7	10							
Sunny	3	6	4	4	5	5	7	3	5	5
Pick	7	7	6	8	6	8	9			
Paul	3	2	1	2	0	5	2	4	5	5
Anu	3	4	3	3	0	0	0	0	1	0
Lily	9	9								

3.2 The Ephemeral reward task - setting with non-visible rewards

In the setting with non-visible rewards, two out of nine birds completed the task within the limit. Sunny reached the criterion on her fourth session, choosing nine optimal options. Paul fulfilled the conditions for passing in his ninth session, where he opted for nine optimal options. Results for the Ephemeral reward task with non-visible rewards are presented in table 3.

Table 3: Results II.

The results representing actual performance of birds on particular testing sessions in the Ephemeral reward task in the setting with non-visible rewards.

Session / Name	1	2	3	4	5	6	7	8	9	10
Odo	6	5	6	5	4	5	6	5	3	4
Sunny	4	7	3	9						
Pick	4	6	7	4	7	6	4	5	4	4
Paul	6	5	4	4	5	3	6	7	9	
Anu	6	2	2	3	5	6	5	5	3	2
Willy	3	4	4	6	6	5	5	5	5	5
Pancake	5	5	5	5	5	5	5	5	5	5
Papu	8	2	5	5	6	3	5	5	5	5
Lily	4	7	5	5	2	7	3	4	7	4

3.3 The Two versus one quantity discrimination task – setting with visible rewards

Regarding the two versus one quantity discrimination task, in the setting with visible rewards, six out of eight birds reached the criterion for passing within 100 trials. Roku did so on his second trial, picking eight out of ten on two consecutive trials. Then Plume and Kermit, reached the criterion on their fourth session by choosing optimally in nine cases. Skipper, as well fulfilled the criterion on his fourth session as the consequence of choosing seven optimal options three times in a row. Diana reached the criterion on her seventh session where she reached at least seven optimal choices third time in a row. The last one that succeeded was Coco. She reached the amount of eight optimal choices on her tenth session, so she was granted one extra session (eleventh) to explore her understanding of the task. On her eleventh trial, she opted for nine optimal options which placed her into the group of successful performers. Table 4 presents the results of the entire group.

Table 4: Results III.

The results representing actual performance of birds on particular testing sessions in the Two versus one quantity discrimination task in the setting with visible rewards. Since Coco opted for eight optimal choices on her tenth session, she was granted eleventh session to prove whether she understood the principle of the task or not.

Session / Name	1	2	3	4	5	6	7	8	9	10
Fay	6	4	5	5	2	5	6	5	7	5
Jean-Luc	5	5	6	5	7	7	5	5	5	5
Skipper	6	7	7	7						
Plume	6	5	7	9						
Kermit	3	3	2	9						
Roku	8	8								
Diana	7	8	4	6	6	8	7	7		
Coco	6	4	8	6	6	4	4	6	6	8 | 9
John	2									

3.4 The Two versus one quantity discrimination task – setting with non-visible rewards

In the quantity discrimination task in which the setting with non-visible rewards was employed, three out of six birds performed successfully. Kermit managed to reach the criterion on his second session, where he chose nine optimal options. Plume made eight optimal choices twice in a row on her fifth and sixth session, which meant that she reached the criterion. And finally, Roku fulfilled the criterion for passing at his seventh trial by choosing optimally in nine cases. For complete results, see table 5.

Table 5: Results IV.

The results representing actual performance of birds on particular testing sessions in the Two versus one quantity discrimination task in the setting with non-visible rewards.

Session / Name	1	2	3	4	5	6	7	8	9	10
Fay	8	5	5	5	5	5	5	5	5	5
Jean-Luc	3	0	1	0	0	0	0	0	0	0
Skipper	2	6	5	5	5	5	5	5	5	5
Plume	5	5	5	5	8	8				
Kermit	10	9								
Roku	2	5	5	5	6	6	9			

3.5 Comparison of the two tasks

Comparing the difficulty of Ephemeral reward task and Two versus one discrimination task, statistical testing did not show any significant difference between the setting with visible rewards (Fisher exact test: P= 0.580) and setting with-non visible rewards (Fisher exact test: P= 0.329). Descriptively, in the setting with visible rewards, 50% of birds were successful at solving the ephemeral reward task compared to 75% successful birds in quantity discrimination task. In the setting with non-visible rewards, it was only 22% of all participating birds that successfully managed to solve the task compared to 50% birds that managed to solve Two versus one discrimination task. The reason why the statistical test did not reveal any significant difference between the two tasks might have been caused by the small and unbalanced sample. The descriptive results are depicted in Figure 33.

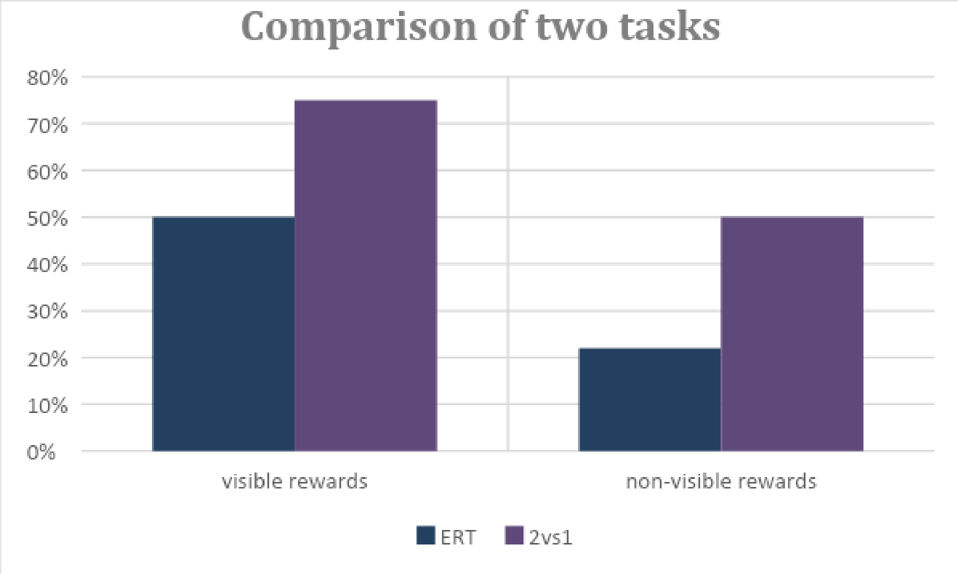


Figure 33: Comparison of two tasks

The descriptive comparison of proportion of subjects that reached criteria on the Ephemeral reward task and the Two versus one quantity discrimination task.

3.6 Comparison of the two settings

The statistical results of comparing the two settings in difficulty did not show any significant difference between the two. More precisely, the within-group comparison of the setting with visible rewards and the setting with non-visible rewards on the ephemeral reward task did not show any statistically significant difference (Wilcoxon Signed Ranks Test: P= 0.655). And in the same vein, the within-group comparison of the setting with visible rewards and the setting with non-visible rewards on the Two versus one quantity discrimination task did not show any statistically significant difference (Wilcoxon Signed Ranks Test: P= 0.317) either. However, this inability to reveal statistical difference might have been again the effect of small and uneven sample size. There are certain hints that the setting with visible rewards might have been easier to solve. Regarding the Ephemeral reward task, while 50% of subjects successfully solved the setting of the task with visible rewards, only 22% solved the variant of the setting with non-visible rewards. In the two versus one quantity discrimination task, there were 75% of subjects successful in accomplishing the task with visible rewards compared to 50% of subjects successful in solving the task with non-visible rewards. Figure 34 shows the descriptive results.

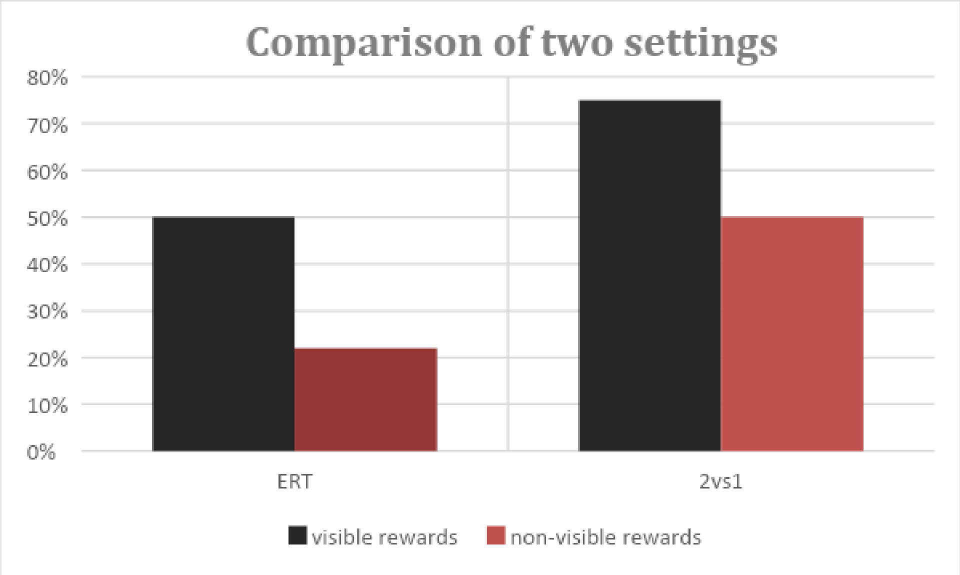


Figure 34: Comparison of two settings

The descriptive comparison of proportion of subjects that reached criteria on the setting with visible rewards and the setting with non-visible rewards.

4 Discussion

The results of experiments show that kea are able to solve the Ephemeral reward task. In general, kea were able to reach the criteria for passing the task in both settings that we employed. Although the statistical analyses did not reveal any significant difference between the two settings, the descriptive results indicate that kea were more successful at the task in the setting with directly visible rewards. Fifty percent of the participating birds solved the task in this setting compared to twenty-two percent of birds that solved the task in the setting with non-visible rewards.

The setting with visible rewards closely resembles the one used by Salwiczek et al. (2012) when conducting experiments on primates. Hence, based on the results of our experiment, we can conclude that kea as a species reached better results than orangutans and capuchins and comparable results as chimpanzees on the Ephemeral reward task in the setting with visible rewards. As was proposed by Zentall et al. (2017a, 2017b) the key factor that is having an impact on the successful performance at this task is the inhibition of action. Hence, regarding the issue from this perspective, kea as a species seem to possess the ability to control their initial urge to obtain the piece of reward. Thus, in terms of cognitive flexibility kea are able to employ cognitive mechanisms that can maximize the food intake. The results of kea parrots seem to be in line with the experimental findings of Pepperberg and Hartsfield (2014), who also employed very similar setting with directly visible rewards when conducting Ephemeral reward task experiment on African Gray parrot. Since African grays previously participated in various experiments (e.g. experiment on delayed gratification Koepke et al., 2015), that helped them to train their impulse control, all three tested African Gray parrots successfully accomplished the task within six sessions. Hence, the results indicate that parrots possess the ability to inhibit their actions (see also Schwing et al., 2017; Koepke et al. 2015) in the direct presence of the food and use cognitive resources as attention, working and long-term memory to deal with a novel task. In recent years, the focus on the inhibition of action was also directed in the research of human cognition. The ability to inhibit one´s actions seems to be one of the essential qualities that help humans function in a complex physical and social environment. Also, it is an important ability that enables abandoning of short-term benefits in favor of considering long-term payoffs, and thus is linked to future planning. In the realm of human cognition, the inhibition of action is studied in the research area dealing with working memory and so-called cognitive flexibility (O'Reilly et al., 2012).

As was previously mentioned, regarding the setting with non-visible rewards, descriptive results showed that kea were not as successful at reaching the criterion for completing the task as in the simpler setting with visible rewards. Only twenty two percent of all subjects (two out of nine subjects) reached the criterion. This was contrary to our initial prediction. Since based on the studies of Pretot et al. (2016a, 2016b), Zentall et al. (2017a, 2017b), Zentall & Case (2018), Murray et al. (2005) we predicted that the non-visibility of rewards in the T-maze setting will redirect cognitive machinery from the urge to obtain the reward as quickly as possible and cognitive resources could be allocated to the environmental cues that are important for solving the task. However, as it turned out, the T-maze setting did not deliver the helping effect in the Ephemeral reward task for kea. The benefit of reducing initial impulsivity of an animal by not seeing the reward did not prove to be of enough power in this setting. We hypothesize that this setting also introduced a lot of complexity into the task, which might have brought some disadvantageous effects. More precisely, a T-maze setting introduced a lot of confounding cues that could grab the attention of a subject and could be falsely considered as the cues that are necessary for a choice. In this fashion, a subject had a lot of possibilities which environmental cue it can choose as the important one and a very short period of time to find out which one it actually is. Moreover, especially in this setting, a lot of our subjects developed a side bias. We consider the side bias to be the consequence of complexity of the setting as well.

In the two versus one quantity discrimination task, the results show that kea can spontaneously discriminate between one piece of reward and two pieces of reward. Despite that our initial expectation was that kea would solve this task, especially the version with the visible rewards quicker than occurred in reality, we can still conclude that kea are motivated to obtain two pieces of reward over one piece of reward.

Regarding the setting with visible rewards, the possible reason that some individuals did not reach the criterion in the period of 100 trials or it took them prolonged period of trials to choose consistently two pieces over one piece of reward, was probably due to the fact that some individuals oftentimes did not completely pay attention to the position of rewards. In some cases, they just automatically opted for the side from which they previously obtained the reward and after a few trials suddenly realized that two pieces of reward are placed at the other plate and then they automatically rushed toward that plate without any paying attention to the actual position of rewards. Moreover, there were other confounding environmental cues, the subject could pay attention to and could falsely consider them as important to follow.

Since there was no previous experiment conducted on quantity discrimination abilities in kea, we set to specifically explore, if kea are able to discriminate between these two quantities. In the quantity discrimination studies on Clark´s nutcracker (Tornick et al., 2015), African gray parrots (Ain et al., 2009) or jungle crow (Bogale et al. 2014), the ability to discriminate among various amounts of different quantities was explored. In these studies, the two versus one quantity discrimination task was just one particular subtask of the entire experimental task. These studies employed the setting with visible food rewards that very closely resembled our setting. It was revealed that Clark´s nutcrackers, African Gray parrots and jungle crows discriminate between different quantities in general. More interesting for our research, it was also revealed that these species discriminate between the one piece of reward and two pieces of reward. The results showed that in these bird species not all the tested individuals successfully accomplished the task, and reaching a hundred percent accuracy on the task was not a common phenomenon, either. Moreover, comparable to our kea group, there were also individuals that developed side bias or paid attention to other environmental cues. It is also necessary to recall that discriminating between two pieces versus one piece of reward (ratio 0.5) is not as straightforward as discriminating between lower ratios, e.g. one piece versus four pieces (ratio 0.25) or one piece versus five pieces (ratio 0.2), which were the subtasks were these species showed high rates of success in solving them. Interestingly, regarding the ratio between one piece of reward versus two pieces of reward (ratio 0.5), in jungle crows (Bogale et al. 2014), the individuals reached a higher rate of success when presented with two pieces versus four pieces of reward (ratio 0.5) or when presented with four pieces versus eight pieces of reward (ratio 0.5). Based on the abovementioned evidence, it would be intriguing to explore how kea parrots would perform on discriminating of various amounts of quantities.

To reach the criterion in the setting with non-visible rewards, more than a pure ability to discriminate between quantities was required. There was a need for the subject to associate certain color of the plate attached to the wall with the number of pieces of reward. From this perspective, the task required more cognitive resources in terms of learning and paying attention to cues that are necessary for successful completing of the task. Here, individuals oftentimes falsely considered side as a cue for solving the task, developing a side bias. However, as we previously mentioned, the side bias can be considered as an effective strategy when dealing with novel and complex setting where each choice of the subject is rewarded.

After all, the major goal of researching whether kea are able to discriminate between two pieces of reward and one piece of reward was to explore if kea will be motivated to choose the ephemeral option to increase their trial output from one piece to two pieces of reward. As the evidence suggests, kea have the motivation to increase their food intake.

Despite the fact that the Two versus one quantity discrimination task seemed to be easier in terms of the complexity of the task, it is still not so easy as to exclude it from the hurdles that the animal subjects needed to overcome in order to learn about the principle of the Ephemeral reward task. If it is hard for some subjects to discriminate between one piece of reward and two pieces of reward, this when presented directly, then using it as a motivation to understand the Ephemeral reward task better is not possible for all subjects. Hence, some of the subjects that failed to reach the criterion in the Ephemeral reward task may just have never understood the difference in the outcome, and for that reason chose randomly.

In spite of the fact, that the statistical analyses comparing the number of successful solvers of the Ephemeral Reward task and Two versus one quantity discrimination task did not reveal any significant difference, descriptive results suggest that to discriminate quantity is easier for kea than to understand the principle of the Ephemeral reward task. The percentage of birds that reached the criteria for successful accomplishment was higher in both settings of the two versus one quantity discrimination task. Considering the principles that are necessary to learn in order to understand and successfully perform at both tasks, the two versus one quantity discrimination task represents a less complex type of task. More precisely, to choose optimally in the quantity discrimination task, it is either necessary to opt for the plate that contains two pieces of reward in case of the setting with visible rewards or to associate a distinctive feature (in our conditions, it was a color) with the two pieces of reward. On the other hand, to choose optimally in the ephemeral reward task, it requires more associations to be made. This applies for both settings. Firstly, a subject needed to connect the distinct option with the specific outcome. And only after that, based on this first association, it was necessary to learn that one of these outcomes is more beneficial in maximization of food intake. Regarding this second step, there are confounding factors that hinder the understanding which of the outcomes is the one that maximizes food intake.

By analyzing performance of individual birds from the perspective of predictive processing framework, certain interesting phenomena can be explained. Especially, in the cases when the setup with non-visible rewards was utilized, some birds developed a side bias for a few sessions, while other birds developed a side bias that persisted during the entire experiment. Here, a theory is offered to explain why it may have been so. From the perspective of predictive processing framework, each individual has its generative model of the world that allows its functioning in the environment. This model predicts the outside world and directs perception (also known as the process of active inference) to the environmental cues that can either confirm the predictions or, via the computation of the prediction error, update the generative model (Clark, 2013; Friston, 2010, Friston et al., 2018). Since our subjects have vast experience with testing, certain expectations about the testing conditions could have been inferred. Most likely, a generative model of each bird contains a strong prior that says - when participating in an experiment, there is always a possibility to obtain a food reward. More precisely, the only way to obtain a piece of peanut for kea is to participate in the experiment. In traditional experimental setting, the rewarding scheme is mostly as follows: When performing as desired, the reward is obtained. On the contrary, nothing is obtained when the correct action was not performed. And this precisely might be the case, how the generative model of the world is constructed, and the priors are set. Therefore, suddenly encountering the experimental setting in which no matter what action is performed, the individual obtains a piece of reward, might be a great violation of the prior that was built into the system by frequent previous experience. Hence, when the subject obtains a piece of reward on a particular side of the T-maze setting, it might consider it as a correctly performed action and does not take into consideration the second option at all. Especially, when such a short time for completing the task is available, it might be tremendously difficult to update one´s generative model and get rid of this prior.

Still, there were birds, that followed different strategies or considered different cues important for solving the task. This can also be explained in terms of predicting processing framework. When an individual is presented with novel and complex settings, there are always many environmental cues that can be considered as important. Since each individual has a subjective and hence different generative model of the world, each individual directs attention to different environmental cues – in Bayesians terms, it assigns different probabilities to cues that might play significant role in the process of making a decision (Clark, 2013; Friston, 2010, Friston et al., 2018). Therefore, some birds could have assigned the highest probability to the side being a most salient cue, while some birds assigned the highest probability to the color of the plate, or to the position of the experimenter or other environmental cue. Moreover, from our human perspective, some birds seemingly did not develop any pattern and made their choices randomly.

Another interesting phenomenon occurred when an individual changed the strategy of choosing. Specifically, when one environmental cue was substituted by a different one. This can also be explained in terms of predictive processing framework. As was already mentioned, each cue has a different posterior probability of being chosen by a particular subject. Certain cues are more probable to be chosen than others, however no cue possesses a 100 percent probability of being opted for. It is likely that for example, weather conditions, morning play, the type of food or many other things, prime the generative model (or direct the attention of the system) on different cues and generative model converges on different hypothesis that explains what is going on in the outside world (Clark, 2013; Friston, 2010; Friston et al., 2018).

From this perspective, the constraint of 100 trials appears to be one of the most difficult features to understand the task and hence make optimal decisions. As is assumed, the system needs a prolonged time to learn (adjust the probabilities) of various cues and to update the prior of traditional rewarding scheme.

4.1 Limitations

Since the research was carried out on the captive kea, our sample size was also limited. Despite the fact, that it is a standard procedure in animal cognition research to use six subjects per group, we assume that the low sample size might have been the reason why statistical inference did not show any significant results. For that reason, we were only able to assess our data descriptively to highlight differences that occurred between the experimental groups.

While it is quite a common procedure to add up some naïve subjects to the second experiment as we did in our research, in this case it caused a problem with unbalanced samples. Hence, we started the first experiment with the Ephemeral reward task in the setting with visible rewards and the Two versus one quantity discrimination task in the setting with non-visible rewards. This decision was based on logistical reasons.

In the Ephemeral reward task with visible setting, there is a hint of a certain pattern being presented. More precisely, the three subjects that successfully solved the Ephemeral reward task made more optimal choices per trial from the beginning of the testing. On the other hand, the three subjects that did not manage to reach the criteria for passing made more sub-optimal choices per trial from the start. This might hint towards building up the preference for the initial choice that they made. However, nothing similar to this pattern was present in the other groups and the number of subjects in the Ephemeral reward task group with visible setting was low (n=6) to draw any significance from this. Therefore, it is considered to be due to randomness.

Lastly, it is important to stress out that to a certain degree, our results are not completely generalizable to the entire species of kea. Even though both tasks were based on spontaneity and no pre-training was required, still our subjects have considerable previous experience with participating in the experiments. It follows that they are more seasoned solvers of abstract problems.

4.2 Recommendations for future research

Regarding the T-maze setting, we pondered, that the wall that divides the T-maze setting into two sides could be made of transparent material – Plexiglas and in this way allow the bird to see what is on the other side of the wall. As was already pointed out, the T-maze setup was designed to remove the reward from the view when making a choice. However, it did also remove from view the other option, once the choice was made. The subjects were required to be motivated on their own to explore the setup to figure out the other option. Doing that within 100 trials, while learning about the cause and effect of their first choice in case of the Ephemeral reward task or about the cause and effect of their only choice in case of the Two versus one quantity discrimination task is an additional hurdle to overcome. Hence, showing them what the alternative is, or even just that there is another alternative which is rewarded, would thus only allow them to have more of the relevant information, without actually changing the nature of what they would need to learn in order to choose optimally.

Another alternative for the setting with non-visible rewards might the setting used by Pretot et al. (2016a), where the distinctively colored cup covered the actual food reward. Which does not seem to introduce as much complexity into the experimental setting as the

T-maze shape of the apparatus. Firstly, the bird would clearly see that there are two options to choose from and secondly, it would have to exert certain activity in order to obtain the covered reward. As this proved to be highly beneficial for capuchins, it may also bring benefit for kea.

It would be also interesting to explore how the idea of Zentall et al. (2017a, 2017b) would apply to the case of kea, that is, whether introducing the time delay, 20-seconds waiting period separating the act of making a choice and obtaining the (first) reward will have an effect on the performance of kea. This would certainly require a pre-training focused on getting kea accustomed to the situation that experimental trial does not end right after the choice is made but there is a need to wait until the reward can be obtained.

5 Conclusion

To conclude we were able to explore all research questions that we initially set. Most importantly, we revealed that kea as a species have the potential to solve the Ephemeral reward task and thus belong to the group of other species, namely: cleaner wrasse, chimpanzee, rhesus macaque, capuchin, African gray parrot which were also successful at solving the task within the limit of 100 trials. Moreover, in the quantity discrimination task, we found out that kea also spontaneously discriminate between one piece of reward and two pieces of reward. Then, we focused on the difficulty of these two tasks and differences of the two settings. Despite the statistical analyses did not show the significant difference of our comparisons, we assume that it was mainly due to the small and unbalanced sample size. In the case of comparing two tasks in their difficulty, descriptive results suggest, the Two versus one quantity discrimination task is less demanding in its nature because higher percentage of individuals reached the criterion in this task. In the case of comparing two settings in their difficulty, descriptive results suggest, that despite to our initial prediction, kea found it easier to reach the criterion when the setting with visible rewards was utilized. Certainly, further studies are necessary to better understand the complexity of factors influencing the understanding of the Ephemeral reward task.

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