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„Delay of gratification in a food exchange task in Goffin cockatoos (*Cacatua goffini*)"

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Vermerk

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Keywords: delay of gratification, food exchange, impulse control, avian cognition

1. Abstract

Evidence for flexible impulse control over food consumption such as temporal discounting is rare outside humans. So far, only a few primate species as well as two corvids have been shown to be able to fully inhibit the consumption of a desirable food item in anticipation for a gain in quality or quantity for more than a minute. Goffin cockatoos (*Cacatua goffini*), a species which previously showed high levels of persistence and patience in other cognitive tasks, were tested in a *delay of gratification task* in which an initial food item could be exchanged against another reward after an increasing time delay. Subjects were able to bridge delays of up to 80s for a preferred food quality and up to 20s for a higher quantity. The decision to wait was influenced, by both, the difference in the quality of the two rewards and the duration of the delay. They tended to trade the initial item more often for the most preferred reward than for a less desirable one and hardly exchanged in controls in which the initial item was of higher value than the expected one. Additionally subjects tended to give up waiting earlier for a small than for bigger gain in value and seemed to assess if a reward is worth waiting for. Furthermore they showed idiosyncratic behavioural patterns when coping with longer delays, which could serve as distraction from consuming the initial food item. Taken together this provides the first evidence for temporal discounting in a psittacine species and hence in an avian species that does not cache food.

2. Zusammenfassung

Flexible Impulskontrolle über Futterkonsumation, wie zum Beispiel zeitliche Diskontierung, wurde bisher selten an anderen Tieren außer Menschen nachgewiesen. Bis jetzt konnten nur wenige Primaten und Corviden die Konsumation eines wohlschmeckenden Futters für mehr als eine Minute unterbinden, in der Voraussicht in naher Zukunft ein qualitativ oder quantitativ besseres Futter im Austausch dafür zu erhalten. Wir testeten diese Fähigkeit an Goffin Kakadus, einer Spezies die sich in anderen Experimenten durch besondere Beharrlichkeit und Ausdauerfähigkeit ausgezeichnet hat. Es zeigte sich, dass Goffin Kakadus in der Lage sind bis zu 80 Sekunden für eine qualitativ besseres Futter und für eine quantitative Steigerung der Futtermenge bis zu 20 Sekunden zu warten. Sie scheinen bei ihrer Entscheidung die benötigte Zeitdauer und auch die Qualität des angebotenen Futters einzukalkulieren, da sie dazu tendierten das zuerst angebotene Futter öfter für ein stark bevorzugtes Futter einzutauschen, als für ein etwas weniger präferiertes. In parallel durchgeführten Kontrollversuchen, in denen das zuerst angebotene Futter quantitativ oder qualitativ wertvoller als das in Aussicht gestellte war, wurde kaum getauscht. Des Weiteren scheinen die Vögel beurteilen zu können ob sich das Warten lohnt, da sie die Tendenz zeigten schneller für ein etwas weniger präferiertes Futter aufzugeben als für ein stark Bevorzugtes. Die Tiere scheinen eine mentale Repräsentation der Zeitdauer zu besitzen, da die Entscheidung, entweder auf ein besseres Futter zu warten oder das zuerst angebotene Futter zu fressen, früher als zufallsmäßig erwartet, oft zu Beginn des Versuches in den ersten Sekunden getroffen wurde. Außerdem zeigten die Tiere idiosynkratische Verhaltensmuster, die möglicherweise darauf abzielen sich bei längeren Wartezeiten von der Konsumation des zuerst angebotenen Futters abzulenken. Unsere Ergebnisse liefern damit den ersten Beweis für zeitliche Diskontierung bei Vögeln, von deren Nahrungsökologie es nicht bekannt ist, dass sie Futter für zukünftige Konsumation verstecken.

3. Introduction

The ability to inhibit an impulse to accept an instant option in anticipation for a delayed, more valuable one, is frequently considered a hallmark aspect of self-control and has long been believed to be a uniquely human attribute (Rachlin et al., 1991; Mischel et al., 1989). In humans, being patient is an advantageous skill in various aspects (Bramlett et al., 2012). Adult humans tolerate delays of month or even years for monetary gains (Hayden & Platt, 2007). Some children at the age of four were capable of waiting 15 to almost 18 minutes for a highly preferred, delayed food reward, depending on the task (Mischel et al., 1972; 1989).

Indeed, most rodents and birds tested waited only a few seconds for a delayed gain and many monkeys wait less than a minute (Abeyesinghe et al., 2005; Ainslie, 1974; Green & Estle, 2003; Hidetoshi et al., 2010; Ramseyer et al., 2006; Stevens et al., 2005). For example, domestic fowls (*Gallus gallus domesticus*) did not wait for six seconds to get a seven second feeding access, if they could opt for the more immediate option: waiting two seconds to get a three second feeding bout (Abeyesinghe et al., 2005). In a study by Ainslie (1974) only three out of ten White Carneaux pigeons (*Columbia livia*) choose the delayed option (the delay duration was not specified, but lay within 7.5 to 15 seconds) in order to obtain a prolonged feeding access. Sprague-Dawley rats (*Rattus norvegicus*) preferred an immediate, smaller amount over a larger delayed reward, if they had to wait more than 12 to 30 seconds, depending on the individual subject (Green & Estle, 2003). Two New World monkeys, cotton-top tamarins (*Saguinus oedipus*) and common marmosets (*Callithrix jacchus*), chose indifferently between an immediate small and a delayed larger reward, if they had to wait no more than five to ten seconds (cotton-top tamarins) and ten to 19 seconds (common marmosets). The maximum delay duration was not assessed (Stevens et al., 2005). Brown capuchin monkeys (*Cebus apella*) waited up to 40 seconds for a food of better qualitative and up to 20s for a quantitative gain. When the reward was 40-fold the initial size, one subject was able to wait for 40 seconds for a bigger quantity (Ramseyer et al., 2006). In fact, being impulsive might even be an efficient strategy, because the probability of achieving a delayed gratification can decrease with time, due to its collection risk: the likelihood of so called "interruptions", that can prevent an animal from consummation, is increasing with time (Stephens et al., 2004). Nevertheless, an ability to assess the increase in value of a delayed gain, relative not only to the value of the initial item but also to the duration of the delay (delay of consumption as well as collection risk) could be of great advantage for the optimization of food intake. However, the ability to evaluate and inhibit potential actions, also those that were advantageous in the past, can help an animal to cope with changing circumstances and is beneficial in making profitable decisions (Murray et al., 2005).

A number of studies within the last decade, show that at least some large brained animals such as some primates and two corvid species, are able to accept delays over a minute and even show outstanding plasticity in decision making relative to the benefits involved (Beran, 2002; Evans & Beran, 2007; Rosati et al., 2007; Dufour et al., 2007; Pelé et al., 2010; Dufour et al., 2011). For example chimpanzees´ (*Pan troglodytes*) decision to wait for a quantitative gain was dependent on the size of the expected reward and the time required to obtain it. They waited four minutes for a piece of food two to eight times the size of the initial item and up to eight minutes for a reward 40 times the size. Furthermore, subjects decided early in a trial whether to wait the entire delay or not, suggesting that they considered delay duration and traded off costs and benefits of waiting at an early point of time (Dufour et al., 2007). Long-tailed macaques (*Macaca fascicularis*) waited a maximum of 160s for a piece of food, eight times the size of the initial food item. For a piece 40 times the size, two subjects managed to wait 21 minutes. Like the chimpanzees in the study of Dufour and colleagues (2007), most macaques seemed to consider the amount of the prospective reward and the delay duration when making their decision (Pelé et al., 2010). The indifference point at which bonobos (*Pan paniscus*), chimpanzees and capuchin monkeys (*Cebus apella*) chose equally often between an immediate small and a larger delayed reward, was on average 74 seconds for bonobos, 123 seconds for chimpanzees and 81 seconds for capuchins (Rosati et al., 2007; Addessi et al., 2011). In a study by Beran (2002) four chimpanzees and one orang-utan (*Pongo pygmaeus*) were able to wait for three minutes for chocolate pieces that were constantly accumulating during the course of the delay. It was not investigated whether this duration was the maximum delay that could be achieved by both species. In 2007, Evans & Beran tested the same chimpanzees again with accumulating candies, with the difference that subjects were given toys for distraction. On average they could inhibit eating for 7.5 minutes in order to get a quantitative gain, the maximum achieved delay was 18 minutes. Recently it was shown that domestic dogs (*Canis familiaris*) were able to wait a maximum of ten minutes and 40 seconds to exchange a small for a larger reward (Leonardi et al., 2012). Authors suggest that this performance was facilitated due to dogs´ domestication process.

There are three benchmark approaches for testing delayed gratification tasks in animals: In a *classical binary decision task*, subjects can decide in advance between an immediate small and a delayed bigger gain (Ainslie, 1974; Hidetoshi et al., 2010; Abeyesinghe et al., 2005; Stevens et al., 2005). In the other two tasks subjects do not need to fixate their decision to wait before the start of delay, but can decide to give up waiting throughout the entire delay by starting to consume the initial item: In the *accumulated delay of gratification task* (*DGT)*, the rewards are cumulatively mounting up in quantity within the subject's reach in the course of the delay and the animal can discontinue the accumulation through interference (e.g. Beran, 2002; Evans & Beran, 2007; Vick et al., 2009). In *exchange DGTs*, subjects are given an immediate reward as a trade currency and can choose to keep it intact throughout the entire delay (in order to exchange it for another expected, delayed reward) or end the trial by starting to eat (e.g. Ramseyer et al., 2006; Dufour et al., 2007; Dufour et al., 2011, Wascher et al. 2012). In contrast to the *accumulated DGT*, which only allows for quantitative testing, the value of the delayed reward can surpass the immediate one either in quantity or in quality in an *exchange DGT*. The renouncement time (the point into the delay at which a subject decides to give up), can provide information about the subject's representation of the delay: if an animal has a presumption about the duration of the delay it should either renounce waiting early in a trial, rather than at a random point of trial time (giving up merely due to a lack of inhibition control) or wait for the entire delay instead (Dufour et al., 2007).

The superior performance of primates in *DGTs* was recently challenged by Dufour et al. (2011) who showed that two corvids, common ravens (*Corvus corax*) and carrion crows (*Corvus corone*) could wait up to 320 seconds (more than five minutes) in a *qualitative exchange DGT*. Corvids waited longer when the disproportion in value was large and if they renounced waiting, they tended to do so instantly rather than in the middle of the delay (Mischel et al., 1989, Dufour et al., 2007). During longer delays, subjects almost always temporarily deposited food before returning it, suggesting that their inhibition control was facilitated through being food hoarders (Dufour et al., 2011). Interestingly, the same crows failed to wait longer than two seconds for higher quantities in an *exchange DGT*, despite choosing higher quantities in a binary preference test (Wascher et al., 2012).

Parrots and corvids frequently are comparable to primates in problem-solving and innovative skills, and it has been suggested that many of the cognitive mechanisms of parrots and corvids are the result of convergent evolution (e.g. Emery et al., 2006). Curiously, when African grey parrots (*Psittacus erithacus*) were tested in an *accumulated DGT*, they failed to inhibit their responses for any longer than three seconds (Vick et al., 2009). Possibly, their performance was hampered by the nature of the task (accumulation vs. exchange) or by the fact that they were asked to maximize quantity, which corvids failed as well in delays longer than two seconds. It is also possible that birds generally lack impulse control when it comes to waiting for quantitative gains.

Therefore, testing another psittacine on a *qualitative* as well as *quantitative exchange DGT* could be highly telling in this respect. We chose the Goffin cockatoo (*Cacatua goffini*), a species, which previously showed high levels of persistence and patience in sequential problem solving tasks (obtaining a food reward locked away by a sequential number of problems; Auersperg et al., submitted) and as feeding generalists (Cahyadin et al., 1994), are likely to possess high levels of flexibility. If Goffins can inhibit food consummation in an exchange task, they should wait for a better quality and/or quantity. If reward type affects their performance, they should wait longer for their most-preferred than for their second-preferred food. If the inhibitory skills of corvids are enhanced by their feeding ecology (food hoarding/caching), the performance of Goffin cockatoos should be inferior to those of corvids.

4. Material and Methods

Fourteen subjects were tested (*4.1*). They received a quality preference test in which preferences for three desirable foods (pecan nut, fried meat, cashew nut) were identified and a quantity preference test to confirm their ability to discriminate between different quantities of the same food (cashew; at 1:2 and 1:6 ratios), either with intact pieces of different sizes or one piece versus several equally sized pieces (Figure 2). Thereafter, they were trained to return an inedible object into the experimenter's hands to receive a reward from the other hand (*4.3*). In the following tests, subjects could exchange an intact initial food item for a visible, expected one of different quality or quantity after different time delays, starting at 2s, then 5s ,10s ,20s ,40s ,80s and 160s until they quit exchanging.

4.1. Subjects

Ten juvenile (5 female, 5 male) and four subadult (2 female, 2 male), hand raised Goffin cockatoos (*Cacatua goffini*) participated in this study (Table 1). The subjects were individually marked with colored leg bands and were housed together (before and after testing) in a large group aviary (see Figure 1; indoors: $45m^2$ ground space, 3-6m high wall to gable; outdoors: 150 m^2 ground space; 3-4,5m high; the indoor area was heated at 20 C° from October through May) enriched with bamboo trees, branches, bathing puddles and wooden chew toys. Three to four sources of fresh fruit, soy-yoghurt, cooked grains, noodles, vegetables and eggs fried in red palm oil were offered in the mornings; basic food mixture (Australian Parrot Loro Parque Mix® supplemented with dried fruits, fennel seeds, milk thistle seeds and Korvimin®) and fresh drinking water were available ad libitum. Testing was conducted in visual isolation from group members in an adjacent experimental compartment (2,5x3m). Subjects were tested for four sessions a week with a maximum of one session per day. All animals had experience being tested in a number of technical problem solving tasks (sequential lock problem, physical support problem, Piagtian object permanence) but none of the animals had experimental history related to the present context. Subjects are not clipped, and participate in all experiments on a voluntary basis: either the door of the testing compartment was opened and the respective bird was called by name, or the experimenter enters the group space and asked the subject to step up on the hand in order to carry it into the testing room.

The described housing conditions comply with the Austrian Federal Act on the Protection of Animals (Animal Protection Act – TschG. BGB1. I Nr. 118/2004). Furthermore, as this study was strictly non-invasive and based purely on behavioural tests, it can be classified as non-animal experiments in accordance with the Austrian Animal experiments Act (§ 2. Federal Law Gazette No. 501/1989).

Table 1 Names, sex, age and division in two testing groups (A, B) of the 14 Goffin cockatoos.

name	sex	hatched	group
Dolittle	male	2011	A
Figaro	male	2007	B
Kiwi	male	2010	B
Konrad	male	2010	A
Muppet	male	2010	A
Pippin	male	2008	A
Zozo	male	2010	B
Fini	female	2007	A
Heidi	female	2010	B
Ladybird	female	2010	A
Mayday	female	2011	B
Moneypenny	female	2010	A
Olympia	female	2010	B
Pims	female	2008	B

Figure 1. The aviary of the Goffin cockatoos. Photos: Alice Auersperg

4.2 Basic Setup for the preference test

During testing the experimenter (IL) sat on a chair at a table (1x1m) opposite the caged bird. When testing started the cage was opened towards the table and the subject was allowed to leave its starting position onto the table once the two hands of the experimenter were laid open simultaneously, revealing their content.

4.2.1 Quality preference test

Three food types (pecan nut, palm-oil-fried beef and cashew nut) were identified out of 17 different food types of the cockatoos´ regular diet (carrot, melon, pomegranate, fresh and dried banana, fresh and dried apple, rice cake, zwieback, corn, roasted egg, pistachio, wal- and hazelnut) on the criteria of always being eaten entirely by each subject and being clearly visually distinct. [1] Therefore a preliminary test was conducted on three days in which equally sized pieces of each of the 17 food items were offered to each bird in random order. For the whole duration of the data collection (December 2011 until September 2012), subjects received the three selected food types only in test conditions.

To assess the birds´ individual preference hierarchy two different, equally sized food items (ca.5x4mm) were presented simultaneously in each hand parallel to the table end, after releasing the bird from the starting position (Fig. 2). Subjects were allowed to eat the item first touched. The hand containing the other item was closed and removed under the table. The animals received 12 sessions of 3 trials, so that all six possible side and food combinations were tested once over two consecutive sessions in random order.

Figure 2. The food combinations of the three selected items (fried meat, pecan nut and cashew nut). Each food combination was offered in both possible side combinations (right or left hand) two times in two consecutive sessions.

[1] This preference test originally also contained a fourth item (pistachio) which was dropped after we failed to find a clear preference distinction between the latter and pecan nut.

4.2.2 Quantity preference test

To confirm their ability to discriminate between different quantities, the birds were tested with chunks of cashew nut at the ratios 1:2 and 1:6, either with intact pieces of different sizes or one piece versus several equally sized pieces (Figure 3).

Subjects received 12 sessions of 6 trials, so that each of the four possible combinations was tested 18 times. For sake of health and to keep the birds motivated, the maximum food intake was controlled, so that in one session a maximum of four cashew nuts could be consumed. Therefore the combinations per session were semi-randomized. The position of the bigger quantity in the left or right hand was randomly altered

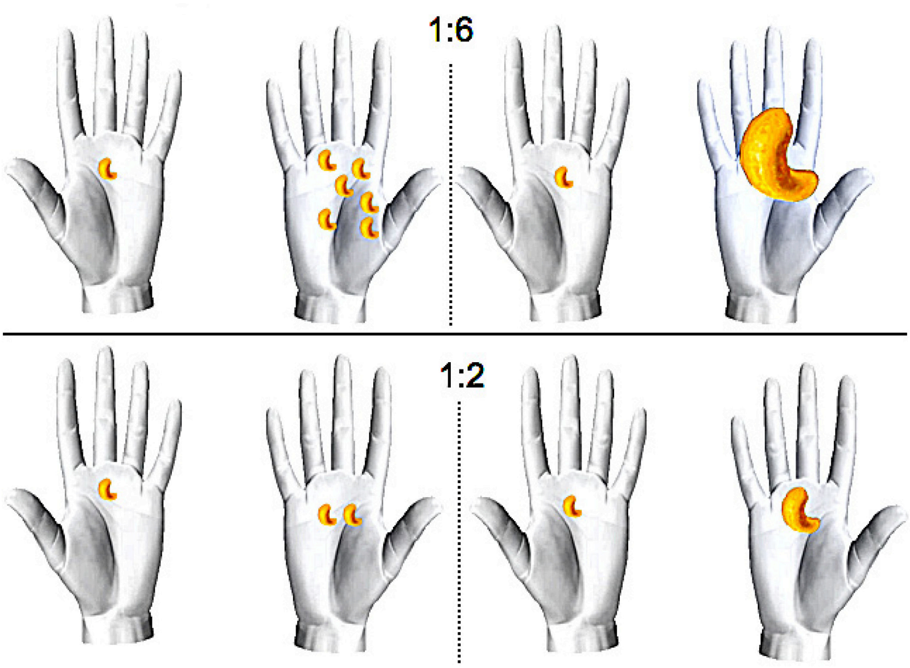

Figure 3. The four possible food combinations of the quantity preference test in the ratios 1:6 and 1:2. One versus two or six equally sized pieces and one smaller piece versus a two times or six times bigger piece of cashew nut. There were two possible side combinations (right or left hand) for each combination.

4.3 Training

Prior to each trial both open hands, one containing an object (small duroplastic toys from kinder ® surprise eggs) and one the food reward, were presented to the bird. Thereafter, the hand containing the reward was closed as soon as the bird left its starting position. If the subject showed the desired behaviour (step 1 to 5, explained below), it was immediately verbally praised and concurrently rewarded by opening the other hand with the food. The hand containing the food was semi-randomly exchanged throughout the training. Animals received six to ten trials per session from step 1 to step 2 depending on individual motivation and ten trials per session in step 3 to 5. Subjects proceeded into the next step after successfully completing 80% of trials within one session per step. Steps were not interchanged within the same session.

Subjects were initially rewarded for biting into the object with their beak (*step 1*). Thereafter, the time span between biting into the object and gratification was gradually increased until subjects held the item in their beaks for three seconds (*step 2*). Once the subject dropped the object, the experimenter caught it with the opened (empty) hand (*step 3*). Subjects were only rewarded if the item was dropped into the empty hand (*step 4*). In the final step the cockatoo was only rewarded for actively and gently placing the object into the experimenter's hand after walking a minimum of three to five steps towards the hand with the object in its beak (*step 5*). The training phase was completed once animals successfully reach criterion for each step.

4.4 Food exchange testing procedure

In the following tests, subjects could exchange an intact initial food item for a visible, expected one of different quality or quantity (Movie 1). In order to maximize the potential for interspecific comparability, two standardized food exchange tasks were used (Dufour et al., 2011; Wascher et al., 2012). For both tasks increasing stages of delay (in seconds) were adopted: 2s, 5s, 10s, 20s, 40s, 80s, 160s, 320s and 640s, following standardized procedures by Dufour et al. (2011). Subjects received seven sessions in the *DQL* and six sessions in the *DQN* of each stage. Testing continued as long as at least one item was successfully exchanged within one stage. During testing the experimenter sat on a chair at the table while a second chair was positioned at the other table end. The starting position of the subject was on the backrest of the chair opposite the experimenter. The bird was allowed to leave its starting position onto the table once the two hands of the experimenter were laid open revealing their content. At the beginning of each trial, the bird was shown both open hands, each containing food of different values or quantities. Once the subject left its starting position, one hand rested at the table end and the bird was allowed to take up the presented item into its beak, while the other hand was moved over the table rim out of the subject's direct reach. The now empty hand was closed to a fist during the delay to avoid untimely returns, whilst the hand containing the tradable food remained visibly displayed out of reach (Fig. 4). During the test, the experimenter wore mirrored sunglasses and avoided lateral head movements and was not speaking to the animals. If the cockatoo nibbled or ate or dropped the initial food item over the table, the trial immediately ended and the hand with the tradable food was removed. If the initial food was intact inside the bird's beak at the end of the delay, the empty hand was reopened to allow the return. Upon the replacement, the hand containing the tradable food was moved into the subject's reach (Fig. 5).

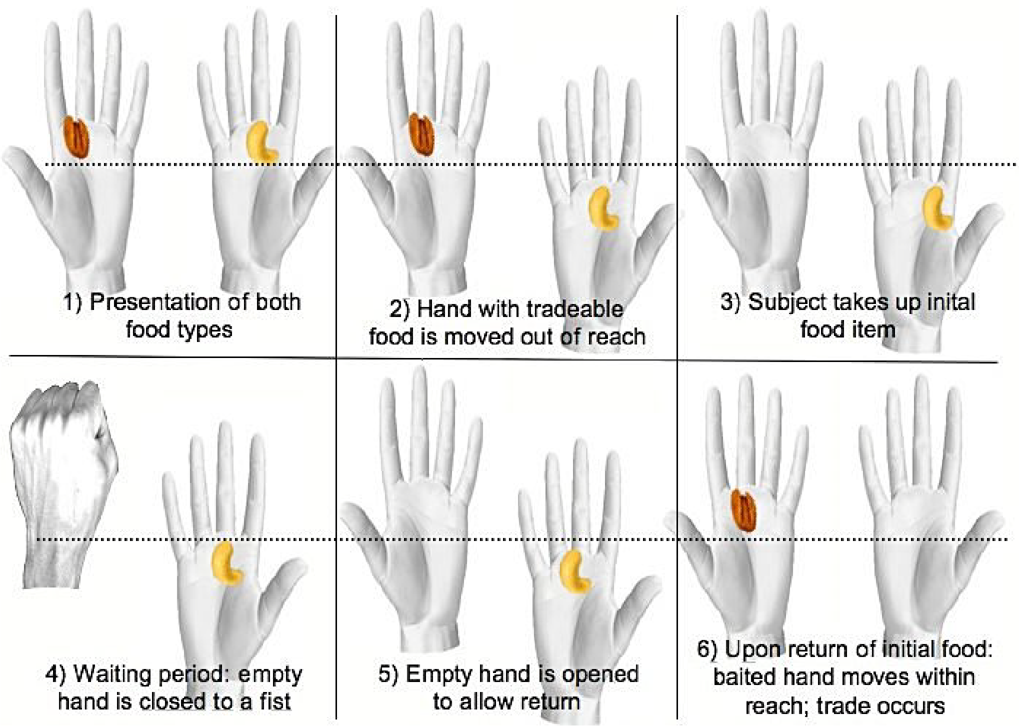

Figure 4. Procedure at the table during the exchange task. Example: *DQL*.

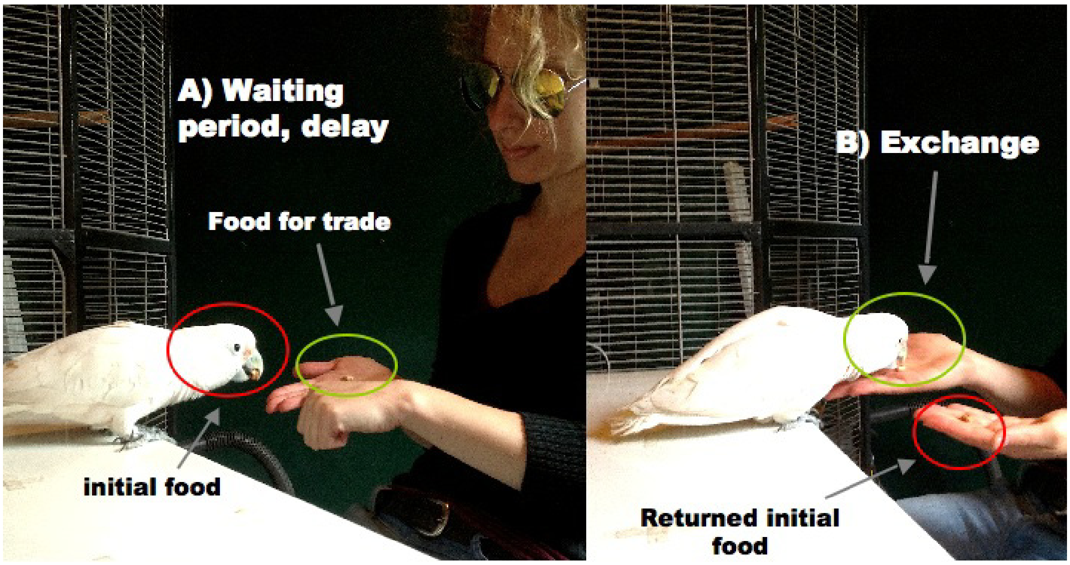

Figure 5. Pictures of the procedure (Photos: Alice Auersperg). Picture A shows the cockatoo with the initial food item in its beak and the position of the hands of the experimenter during the waiting period. Picture B shows the successful exchange of the intact initial item against the reward at the end of the delay. Example: *DQL*.

4.4.1 Delayed food quality exchange test (DQL)

Three food types were used, which could be clearly rated as low, medium and high quality for each bird (pecan nut, fried meat and cashew nut). Each of the seven sessions comprised nine trials (the last session six trials): three control trials (to control for subjects falling into a strategy to wait: in controls the birds received the high-value food (cashew) as initial item and could trade it for alternating low- or medium-value foods, pecan an meat) and six trials in which they could exchange an initial item for their most or for a second preferred food reward. For sake of comparability the same initial item was used for all subjects: pecan nut. Every possible combination was tested 20 times per stage and each control (medium, low) 10 times. Sides of presentation on the two hands were semi randomly balanced across sessions.

4.4.2 Delayed food quantity exchange test (DQN)

As in the quantity food preference test, the two ratios (1:2 and 1:6 of cashew nut) were randomly offered both in pieces and as a whole. This, as well as the side of the bigger quantity (left or right hand), were semi-randomly balanced across sessions, so that within one stage every possible side and food combination was tested 12 times. Subjects received 6 trials in each of the six session, each stage containing 12 balanced control trials (6x 1:2 whole, 6x 1:6 whole) in which the bigger quantity was offered as the initial item and the smaller one as the tradable item. Subjects received a lesser amount of trials than in the *DQL* in order to avoid over-saturation. The maximum pay-off possible (4 nuts) was still below the amount the birds could potentially eat before saturation.

4.5 Statistical Analysis

All data was HD video recorded (JVC HD Everio Camcorder GZ-HM30) and coded in situ as well as from the videos. To randomize the test-combinations a randomize machine (www.random.org) was used. 20% of the video data was rated for reliability by a naïve observer. Interobserver reliability was excellent (cohen's kappa value=0.98). Microsoft Access and Excel 2010, IBM SPSS 17.0 and two tailed, non-parametric statistics for analysing the data was used.

4.5.1 Renouncement time

As has been done in previous studies on *exchange DGTs* (Dufour et al., 2007 and 2011; Pelé et al. 2010; Pelé et al. 2011) the time, at which subjects gave up waiting and started eating the reward before the end of the trial, was analysed. This was done in order to test, whether the cockatoos had obtained a representation of the length of the delay (under the condition of having experienced the delay duration at least once) and could therefore decide early in a trial whether it was worth waiting it out or not. As in the previous studies (Dufour et al., 2007 & 2011) a Kaplan Meyer survival analysis was used to calculate the observed and expected survival function for each give up point. The survival analysis included the give up points as well as trials in which subjects waited the entire delay duration to exchange the initial item for a prospective reward (censored data). Thereafter an adjusted Kolmogorov-Smirnov test was used to compare the observed survival function to the expected distribution of give up times (with a constant give up chance under 0-hypothesis). Significant differences between the observed and the expected distribution indicate that a subject renounced waiting earlier than would be expected by chance. The analysis was run for all reward types and delays in the *qualitative* and *quantitative DGT* for individual subjects.

5. Results

5.1 Quality preference test

On average, subjects chose cashew nut as the most preferred food item (mean choice over meat and pecan = 84.23 %), meat as the medium item (mean choice over cashew and pecan: 42.06%) and pecan as the least preferred of the three items (mean choice over any cashew and meat: 23.71%; Table 2). Subjects chose cashew nut over pecan nuts and cashew nuts over meat significantly above chance levels (One sample Wilcoxon; Z=3.39; p= 0.001; Z=3.81; p=0.005) but this is not conventionally significant for meat over pecan (One sample Wilcoxon; Z=1.07; p=0.285); this is because eight birds preferred meat over pecan and six birds preferred pecan over meat, see Table 2). If individual preferences are taken into account, the birds preferred the items of highest value significantly above chance over both remaining items and the medium over the low (One Sample Wilcoxon test; Z=3.304; p=0.001; Z=3.399; p=0.001; Z=3.316; p=0.001). For analysing the effects of food quality on waiting durations and give-up times, individual preferences were taken into account (see Table 2): In one test condition, subjects could exchange the initial item (pecan) for their most preferred food (MPF; n=14), which was for 12 birds cashew and for two birds meat. In the other test condition, subjects could exchange the initial item for their second preferred food (SPF; n=8), which was for six birds meat and for two birds cashew. The remaining six birds, which preferred the initial item (pecan) as their second preferred food item, could exchange in one test condition for cashew (MPF) and in the other test condition for meat, which was their least preferred food (LPF; n=6).

Table 2. Individual food preferences in percentage of choice for one item over another for the three food combinations later used in the *quality exchange tasks*. Brackets refer to the resulting food hierarchy ranked from lowest to highest preference for each subject (m=fried meat; p=pecan nut; c=cashew nut).

Subjects	*Hierarchy*	Combination 1		Combination 2		Combination 3	
		pecan	***meat***	***pecan***	***cashew***	***meat***	***cashew***
Olympia	p<m<c	8,3	91,7	0	100	41,7	58,3
Figaro	p<m<c	9,1	90,9	0	100	8,3	91,7
Kiwi	p<m<c	33,3	66,7	0	100	41,7	58,3
Muppet	p<m<c	10	90	0	100	8,3	91,7
Heidi	p<m<c	8,3	91,7	8,3	91,7	41,7	58,3
Zozo	p<m<c	20	80	0	100	0	100
Moneypenny	p<c<m	0	100	16,7	83,3	75	25
Konrad	p<c<m	0	100	0	100	58,3	41,7
Dolittle	m<p<c	91,7	8,3	0	100	8,3	91,7
Mayday	m<p<c	75	25	33,3	66,7	25	75
Pippin	m<p<c	66,7	33,3	8,3	91,7	8,3	91,7
Ladybird	m<p<c	75	25	41,7	58,3	16,7	83,3
Fini	m<p<c	58,3	41,7	0	100	0	100
Pims	m<p<c	100	0	0	100	0	100
average	p<m<c	39,69	60,31	7,73	92,26	23,8	76,19
SE		9,74	9,74	3,65	3,65	6,413	6,41

5.2 Quantity preference test

Subjects chose the larger quantity in the 1:2 (mean choice 2 over 1 = 68.76 %), as well as in the 1:6 ratio (mean choice 6 over 1 =81.54%; Table 3). There was no significant difference in subject's choices between the 1:2 ratio of one versus two equally sized pieces and the 1:2 ratio of a smaller versus a bigger piece nor between the 1:6 ratio of one versus six equally sized pieces and the 1:6 ratio of a smaller versus a bigger piece (paired Wilcoxon test; Z=0.42; p=0.674; Z=0.94; p=0.345). The data for both 1:2 and 1:6 sub-conditions was therefore pooled for further analysis. Subjects chose the higher quantity above chance in both the 1:2 and the 1:6 ratio (one sample Wilcoxon test; Z=3.29; p=0.001; Z=3.3; p=0.001), but chose the higher quantity more often in the 1:6 than in the 1:2 ratio (paired Wilcoxon test; Z=3.297; p=0.001).

Table 3. Individual preferences in percentage of choice for one item over another for the four food combinations later used in the quantity exchange tasks. (1=1/6 piece of cashew; 2=2/6 cashew, either in equally sized pieces or as a whole; 6= an entire cashew nut, either in 6 equally sized pieces or as a whole).

	Combination 1		**Combination 2**		**Combination 3**		**Combination 4**	
Subjects	*1*	*2 (pieces)*	*1*	*2 (whole)*	*1*	*6 (pieces)*	*1*	*6 (whole)*
Dolittle	22,2	77,8	33,3	66,7	11,1	88,9	16,7	83,3
Figaro	44,4	55,6	27,8	72,2	11,1	88,9	11,1	88,9
Kiwi	23,5	76,5	38,9	61,1	5,6	94,4	38,9	61,1
Konrad	52,9	47,1	29,4	70,6	50	50	22,2	77,8
Muppet	11,1	88,9	44,4	55,6	5,6	94,4	11,8	88,2
Pippin	16,7	83,3	33,3	66,7	11,1	88,9	22,2	77,8
Zozo	16,7	83,3	50	50	5,6	94,4	33,3	66,7
Fini	22,2	77,8	22,2	77,8	16,7	83,3	5,6	94,4
Heidi	44,4	55,6	38,9	61,1	33,3	66,7	38,9	61,1
Ladybird	29,4	70,6	23,5	76,5	13,3	86,7	25	75
Mayday	50	50	27,8	72,2	22,2	77,8	16,7	83,3
Moneypenny	16,7	83,3	33,3	66,7	11,1	88,9	22,2	77,8
Olympia	38,9	61,1	27,8	72,2	27,8	72,2	11,1	88,9
Pims	31,3	68,8	23,5	76,5	11,1	88,9	5,6	94,4
average	30,03	69,98	32,45	67,56	16,83	83,17	20,09	79,91
SE	3,69	3,69	2,19	2,19	3,38	3,38	2,96	2,96

5.3. Delayed food exchange tests

Subjects required six to 13 days, eight days on average to reach the criterion for testing. All subjects entered the test directly after the training procedure with an inedible token (*4.3*). The cockatoos were divided into two sex- and age- specific equal groups (N=7 per group, see *4.1*, table 1). Group A first completed the *DQL* (*4.4.1*), secondly the *DQN* (*4.4.2*). Group B started with the *DQN* and completed the *DQL* afterwards.

All birds in group A immediately started exchanging in the DQL. The subadult female "Fini" failed to exchange in the first session of the *DQL* and therefore entered the *DQN*. But after showing high levels of impulsive control in the quantitative context, she was again tested qualitatively and was successful. Five out of the group A birds exchanged for higher quantities in the DQN.

All individuals of group B failed in the first session of the quantitative exchange. All corvids in the studies of Dufour et al. (2011) and Wascher et al. (2012) had received the *DQL* before *DQN*. Therefore, after successful qualitative exchanging we decided to test all B individuals again in the quantitative context and three of them started to exchange.

5.3.1 *Delayed quality exchange (DQL)*

All 14 subjects readily exchanged the initial item (pecan) for preferred food items at 2s and 5s delays. Half of the birds waited 40s and three even up to 80s (maximum delay accepted) (Table 4). The mean percentage of exchanges gradually decreased as waiting time increased (Figure 6). Exchanges in the two control conditions started at low rates and vanished at 10s.

Table 4. Percentage of exchanges of the initial food item (pecan) against MPF and SPF/LPF (see food hierarchy) for each delay (2s-160s) for each individual subject; shaded area: subject dropped from the test.

	food	**2s**		**5s**		**10s**		**20s**		**40s**		**80s**		**160s**	
Individuals	hierarchy	MPF	S/LPF	MPF	S/LPF	MPF	S/LPF	MPF	S/LPF	MPF	S/LPF	MPF	S/LPF	MPF	S/LPF
Olympia	p<m<c	95	100	100	94,7	100	89,5	95	80	58,8	61,1	36,8	45	0	0
Kiwi	p<m<c	84,2	83,3	94,7	88,9	94,4	100	94,4	78,9	68,8	58,8	11,8	11,8	0	0
Muppet	p<m<c	100	100	100	88,9	95	100	100	100	68,4	26,3	10,5	0	0	0
Konrad	p<c<m	100	95	100	94,7	100	94,4	83,3	83,3	26,3	55,6	0	0		
Moneypenny	p<c<m	95	89,5	100	90	61,1	70,6	94,7	100	10,5	22,2	0	0		
Zozo	p<m<c	95	94,4	60	30	55,6	0	0	0						
Figaro	p<m<c	94,4	68,8	27,8	12,5	0	0								
Heidi	p<m<c	90	100	47,4	50	0	0								
Fini	m<p<c	80	35	85	10	89,5	15	84,2	0	33,3	5,6	0	0		
Pippin	m<p<c	100	30	89,5	5	90	0	88,2	10	42,1	0	0	0		
Mayday	m<p<c	100	15	55,6	5	27,8	0	6,3	0	0	0				
Dolittle	m<p<c	50	31,6	73,7	35	10	0	0	0						
Ladybird	m<p<c	66,7	23,5	50	0	0	0								
Pims	m<p<c	83,3	15	47,4	0	0	0								

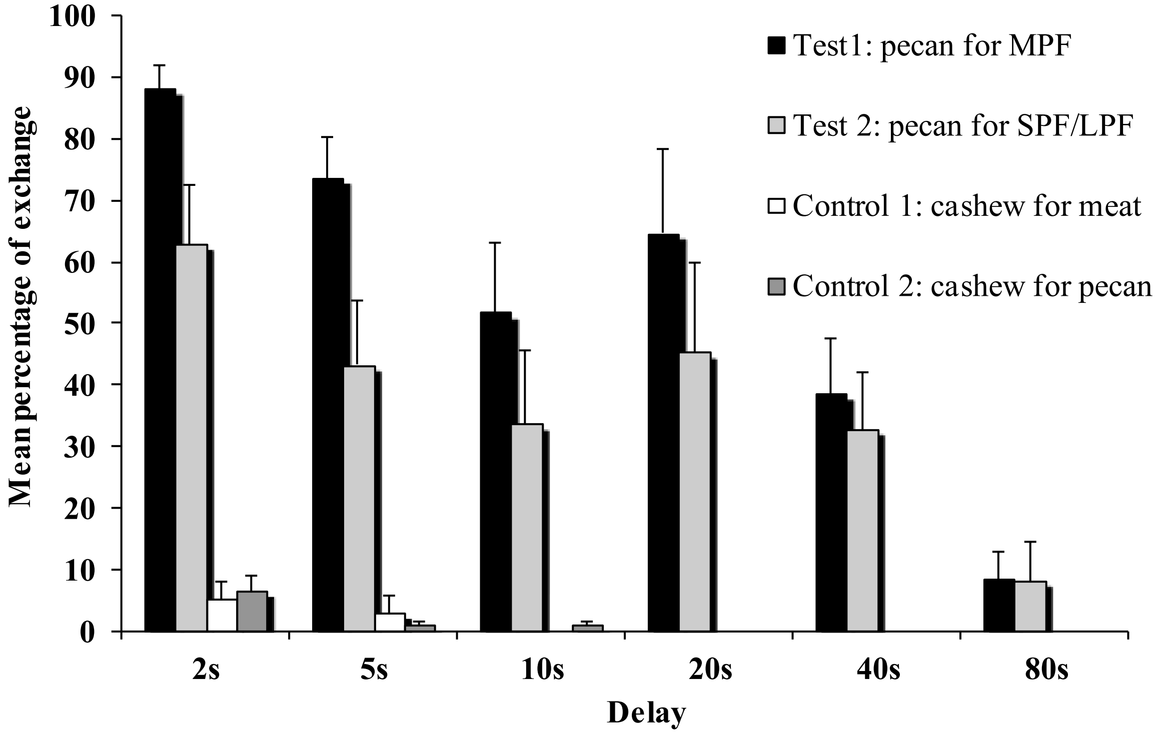

Figure 6. Mean percentage of successful exchanges in the *DQL*, for 2s to 80s delays, in the two test and the two control conditions. Subjects that had not yet been dropped from the test, but did not exchange for a certain condition/delay are still accounted for. Note: Test 2 includes exchanges for SPF (n=8) and LPF (n=6).

Within a certain delay and condition, birds either did not exchange at all, or did so at high rates until ca. 20s delays before performance dropped (Table 4). The mean percentage of exchanges is shown in Table 5. The mean number of exchanges for the most preferred food item (MPF, for 12 birds cashew and for two meat) varied between delays (Friedman's ANOVA; X^2=16.435; p=0.012), with subjects exchanging more in 5s than 10s (Wilcoxon; Z=2.591, p=0.01), more in 20s than 40s (Z=2.521, p=0.012) and more in 40s than 80s (Z=2.201, p=0.028). A similar pattern was found for SPF (n=8 birds; Friedman's ANOVA; X^2=15.865; p=0.014). Furthermore, the eight birds exchanged significantly more often for the MPF than for their SPF in 5s delays (Z=2.383; p=0.017; paired tests for delays over 20s could not be conducted due to decreased sample size, but there is a trend that they exchanged more often for the MPF than for their SPF (see Table 5)).

Table 5. Mean percentage of exchanges for MPF and SPF/LPF. Subjects that did not exchange for a particular delay are excluded. (NE= no successful exchange in the delay).

	number of subjects	**2s**	**5s**	**10s**	**20s**	**40s**	**80s**
MPF	n=14	88.11 ± 3.90	73.65 ± 6.69	72.34 ± 10.23	80.76 ± 10.83	44.03 ± 8.43	19.70 ± 8.56
MPF	n=8	94.20 ± 1.83	78.74 ± 10.34	84.35 ± 8.31	93.48 ± 2.75	46.56 ± 11.90	19.70 ± 8.56
SPF	n=8	91.38 ± 3.84	68.71 ± 11.67	75.75 ± 15.79	88.44 ± 4.77	44.8 ± 8.46	18.93 ± 13.47
MPF	n=6	80,00 ± 7.93	66.87 ± 7.48	54.33 ± 20.77	59.57 ± 26.66	37.70 ± 4.40	NE
LPF	n=6	25.02 ± 3.52	9.17 ± 5.39	3.75 ± 3.75	3.33 ± 3.33	2.80 ± 2.80	NE

5.3.2 Delayed quantity exchange (DQN)

Cockatoos also responded to the quantity of the offered reward. Eight out of 14 cockatoos exchanged lower for higher quantities for up to 20s delays (Table 6).

Table 6 Percentage of exchanges of one piece against two or six pieces of cashew nut for each delay (2s-20s) for the eight birds that exchanged in the *DQN*; shaded area: subject dropped from test; Average values: subjects that did not exchange for a particular delay are excluded.

	2s		**5s**		**10s**		**20s**	
Individuals	1:2	1:6	1:2	1:6	1:2	1:6	1:2	1:6
Dolittle	16,7	25,0	0,0	16,7	0,0	0,0		
Fini	16,7	25,0	41,7	75,0	33,3	66,7	0,0	0,0
Konrad	8,4	25,0	8,4	8,4	10,0	8,4	0,0	8,4
Ladybird	40,0	25,0	8,4	8,4	0,0	0,0		
Pippin	25,0	25,0	0,0	0,0				
Figaro	33,3	58,4	56,7	16,7	20,0	18,4	0,0	0,0
Heidi	0,0	16,7	0,0	0,0				
Mayday	8,4	8,4	0,0	0,0				
average	18,55	26,04	23,01	25,01	21,10	31,12	0,00	8,35
SE	4,78	5,09	11,05	12,64	6,75	18,00		

Exchanges in the two control conditions started at low rates and vanished at 5s (Figure 7 below). However, they exchanged at lower rates than in the *DQL* (see Table 7 below). The exception was one female (“Fini”) that still exchanged at high rates in the 5s and 10s delay in the 1:6 condition (Table 6). As in the preference test (*5.2*), there were no significant differences in the percentage of exchanges for the larger quantities presented in equally sized pieces or as a bigger piece, neither for the 1:2 nor for the 1:6 ratios (Wilcoxon test; all p>0.05). Moreover, there were no significant differences in the percentage of successful exchanges between the 1:2 and the 1:6 ratio or in the percentage of exchanges between the two ratios for any of the stages (Wilcoxon tests; all p>0.05).

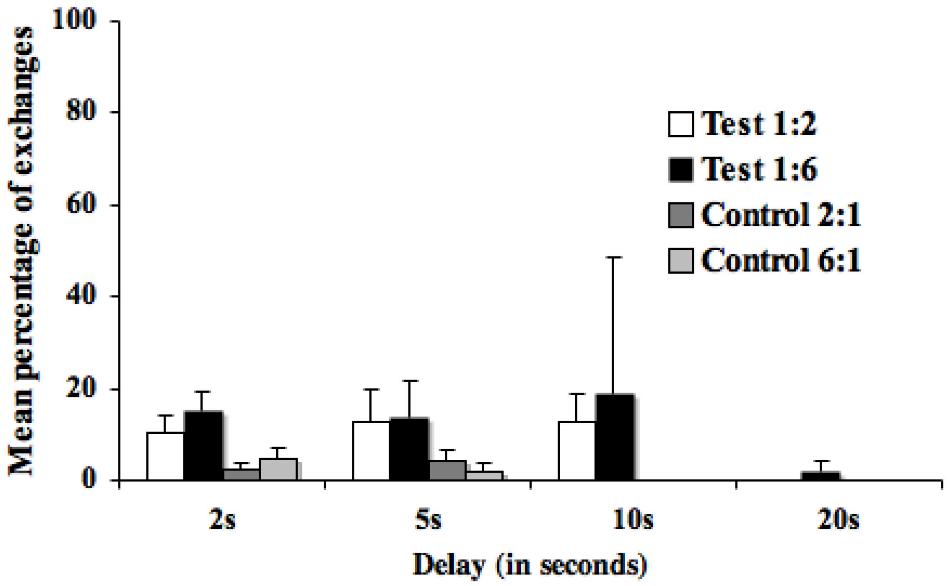

Figure 7. Mean percentage of successful exchanges in the *DQN*, for 2s-20s delays, for the two test conditions and the two control conditions (at ratios 1:2 and 1:6). Subjects that had not yet been dropped from the test, but did not exchange for a certain condition/delay are still accounted for (n=14).

Table 7 Maximum delay (in seconds) achieved in two conditions (MPF, SPF/LPF) of the qualitative exchange task (*DQL*) and the two ratios (1:2, 1:6) of the quantitative exchange tasks (*DQN*).

Subjects	DQL (MPF)	DQL (SPF,LPF)	DQN (1:6)	DQN (1:2)
Olympia	80	80	no exchange	no exchange
Kiwi	80	80	no exchange	no exchange
Muppet	80	40	no exchange	no exchange
Konrad	40	40	20	10
Moneypenny	40	40	no exchange	no exchange
Zozo	10	5	no exchange	no exchange
Figaro	5	5	10	10
Heidi	5	5	2	no exchange
Fini	40	40	10	10
Pippin	40	20	2	2
Mayday	20	5	2	2
Dolittle	10	5	5	2
Ladybird	5	2	5	5
Pims	5	2	no exchange	no exchange

5.3.3 Sex Differences

We did not find any sex differences above conventional significance levels, in the *quality exchange tasks*, neither in the mean percentage of exchanges per stage nor in the longest waiting time (for MPF and SPF) and in the *quantity exchange task*, neither in the mean percentage of exchanges nor in the longest waiting time (for each, the 1:2 and the 1:6 ratio; Mann-Whitney U tests; $p>0.05$).

5.3.4 Comparison with corvid data (Dufour et al., 2011)

Comparing the percentages of exchange (*DQL*) with those of Dufour and colleagues (2011), it was found that cockatoos exchanged significantly more often than ravens in 2s and 5s delays (Mann-Whitney U-test; $Z=2.836$; $p=0.005$; $Z=2.885$; $p=0.004$; paired tests for longer delays were not conducted due to small sample sizes in corvids). Furthermore cockatoos were able to bridge delays up to 20 seconds for a quantitative gain, whereas carrion crows failed to wait more than two seconds (Wascher et al., 2012).

5.3.5 Renouncement time

As observed in corvids, some Goffins renounced waiting earlier into a delay than predicted by chance in the *DQL* (Table 8). The exceptions were two birds (Konrad, Olympia) that never gave up earlier than predicted in both conditions. The six birds that preferred meat as their least preferred food item (Table 2), renounced waiting earlier when the prospective reward was meat and often did not exchange for this condition, half of them additionally gave up waiting earlier for their most preferred food (cashew). All other subjects renounced waiting earlier than predicted by chance in at least one delay. For some birds values that indicate early renouncement to wait, tend to be stronger for the SPF than for the MPF (see Table 8; Kiwi: 80s delay, Muppet: 80s delay, Zozo 5s&10s delay, Figaro: 5s delay, Heidi: 5s delay). Furthermore, the eight birds which preferred the initial item (pecan) as least preferred, gave up waiting significantly later in 5s delays for their MPF than for their SPF (Wilcoxon test; $Z=2.384$, $p=0.017$; paired testing for delays over 20s could not be conducted due to decreased sample sizes). In the *DQN*, subjects mostly renounced waiting earlier into a delay than predicted by chance (Table 9). There was no significant difference in the mean give up times between the 1:6 and 1:2 ratios (Wilcoxon tests; p>0.05).

Table 8 Results of adjusted Kolmogorov-Smirnov analysis for both conditions (MPF,SPF/LPF) of the *DQL*: (*: p < 0.05; **: p< 0.01; n= bird did not exchange in this condition, no err= bird always exchanged; NE= bird never exchanged and did therefore not experience delay duration; hence cannot be included in analysis; NT: not tested).

Subjects	food-	5s		10s		20s		40s		80s	
	hierarchy	SPF/LPF	MPF	SPF/LPF	MPF	SPF/LPF	MPF	SPF/LPF	MPF	SPF/LPF	MPF
Olympia	p<m<c	0,23	no err	0,23	no err	0,33	0,08	0,42	0,46	0,95	0,92
Kiwi	p<m<c	0,47	0,23	no err	0,24	0,58	0,17	0,8	0,34	2.11**	1.67**
Muppet	p<m<c	0,89	no err	no err	0,07	no err	no err	1,16	0,3	1.79**n	1.73**
Konrad	p<c<m	0,45	no err	0,03	no err	0,27	0,23	1,08	0,64	NE	
Moneyp.	p<c<m	0,45	no err	0,69	1,12	no err	0,02	1,15	1,86**	NE	
Zozo	p<m<c	1,38*	0,45	3.35**n	1,18	NE		NT			
Figaro	p<m<c	2,67**	1,65**	NE		NT					
Heidi	p<m<c	1.55**	0,97	NE		NT					
Fini	m<p<c	3.35**	0,45	3.58**	0,36	3,30**n	0,29	3,77**	0,96	NE	
Pippin	m<p<c	4.25**	0,67	4.25**n	0,17	4.02**	0,24	2.46**n	0,89	NE	
Mayday	m<p<c	3.8**	0,3	3.8**n	1,38*	3.58**n	2.75**	NE		NT	
Dolittle	m<p<c	2.91**	0,69	4.25**n	0,54	NE		NT			
Ladybird	m<p<c	4.02**n	2.91*	NE		NT					
Pims	m<p<c	4.25**n	2.29**	NE		NT					

Table 9 Results of adjusted Kolmogorov-Smirnov analysis for *DQN*: (*: p < 0.05; **: p< 0.01; n= bird did not exchange in this condition; NE= bird never exchanged in both conditions and did therefore not experience delay duration; hence cannot be included in analysis; NT: not tested). Six birds (Kiwi, Moneypenny, Muppet, Olympia, Pims, Zozo) never exchanged in this task.

Subjects	**2s**		**5s**		**10s**		**20s**	
	1 : 2	***1 : 6***	***1 : 2***	***1 : 6***	***1 : 2***	***1 : 6***	***1 : 2***	***1 : 6***
Dolittle	2.89**	2.6**	1,81** n	0,95	NE		NT	
Figaro	2.31**	1.44**	1,26**	1,67**	1,81**	1.41**	NE	
Fini	2.89**	2.6**	1.44**	0,87	0,67	0,33	NE	
Heidi	3.18** n	2,53**	NE		NT			
Kiwi	NE		NT					
Konrad	3.18**	2.6**	1,51**	2.02**	1,67**	2.53**	2.60** n	1.73**
Ladybird	2.11**	2.60**	1.51**	2,33**	NE		NT	
Mayday	3.18**	3.18**	NE		NT			
Moneypenny	NE		NT					
Muppet	NE		NT					
Olympia	NE		NT					
Pims	NE		NT					
Pipin	2.6**	2.6**	NE		NT			
ZoZo	NE		NT					

There is an alternative, lower level explanation for giving up earlier than predicted: the waiting and exchange behaviour could have been extinguished by several consecutive renouncements to wait in a given delay (Dufour et al., 2011; Dufour et al., 2007). Therefore the waiting duration per trial at the last delay, where subjects successfully exchanged at least one time, were examined (see 9. Appendix; *DQL*: Figure 8, *DQN*: Figure 9). Although subjects renounced waiting in several trials, most birds subsequently decided to wait again for the whole duration of the delay to obtain the preferred food reward.

5.3.6 Distraction Behaviours

Longer delays ≥ 10s) were often characterized by a number of idiosyncratic behaviours, which seemed to be frustration-induced, but could have served to self-distract subjects as a beneficial side effect (see Table 10). Almost always the initial food item was rotated in the beak with the tongue, in more than the half of the trials subjects were walking right and left at the table edge in front of the experimenter and stretched their body and beak towards the hand. Unlike both corvid species, Goffins hardly ever deposited the food on the table and seemed to have difficulties leaving it there, immediately picking it up again (see behavior 7, Table 10). In cases where birds did not exchange, they usually ate the initial item (95.2%, *DQL* & *DQN* combined). Rarely it was dropped off the experimental table (3.1%, *DQL* & *DQN* combined). In 1.0% of cases, subjects failed to give back the initial item after delay duration had elapsed (*DQL* & *DQN* combined).

Table 10 Percentage of trials containing self-distractive behaviors 1-9 (1= manipulation with food, 2= rotating food in the beak, 3= lateral swaying movements, 4= stretching body/beak towards the hand, 5= walking/running right and left, 6= walking back and forth from starting position, 7= put the initial item onto the ground and immediately pick it up again, 8= turning around own body axis, 9= touch the ground with the beak) for each subject from 10s delay until last successful stage.

Subjects	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Dolittle	50,0	100,0							
Fini		81,1		43,4	37,7	3,8			1,9
Konrad	11,8	83,5	1,2	47,1	65,9	2,4	1,2	18,8	2,4
Ladybird									
Moneypenny	15,4	87,7	1,5	21,5	60,0	70,8	1,5	9,2	15,4
Muppet	71,3	90,8	5,7	48,3	64,4	4,6	2,3	27,6	
Pippin	4,7	72,1	0,0	62,8	93,0	4,7	2,3	4,7	32,6
Figaro		100,0		100,0	100,0				
Heidi									
Kiwi	21,3	97,9	60,6	95,7	61,7		2,1	21,3	31,9
Mayday	83,3			66,7				16,7	33,3
Olympia	100,0	26,9		15,7	4,6	1,9	0,9	27,8	6,5
Pims									
Zozo	40,0	90,0		20,0			10,0		10,0
average	44,2	83,0	13,8	52,1	60,9	14,7	2,9	18,0	16,7
SE	11,4	6,8	11,7	9,4	10,6	11,2	1,2	3,3	4,9

6. Discussion

Our results indicate that Goffin cockatoos clearly possess impulse control over extended delays in *DGT*s. They further seem to attribute value to tokens and to tolerate loss of an initial item in anticipation for a gained compensation. Like some primates, dogs and corvids, they acted much like economic agents, flexibly trading-off between immediate and future benefits relative, not only to the length of delay but also to the difference in trade value between the currency and the item on auction (Dufour et al., 2007; Dufour et al. 2011, Leonardi et al., 2012).

Goffins tended to trade the initial item more often for the most preferred food than for a less desirable one and hardly ever exchanged in controls in which the initial value was higher than the expected. They tended to either renounce waiting early in a trial or waited the entire delay, indicating an ability to assess the duration of the delay (Dufour et al., 2007; 2011). Furthermore, subjects seemed to additionally judge if a gain is worth waiting for relative to its expected value, tending to put more effort into waiting for the most valued food than for a less valued one. These results are similar to those found in corvids and apes: in the study of Dufour and colleagues (2011) the two corvid species also exchanged significantly more often for a highly preferred food. Furthermore most subjects also gave up waiting significantly earlier than predicted by chance and they tended to renounce waiting later for their most than for a less preferred food item, which indicates that they, like the Goffins, put more effort into waiting for their most preferred food than for a less preferred one. Similar to the carrion crows, ravens and Goffin cockatoos, chimpanzees and long-tailed macaques could anticipate the delay duration and decided earlier than predicted by chance whether the reward is worth waiting for or not (Dufour et al., 2007; Pelé et al., 2010).

Like in the study of Dufour and colleagues (2011), in the present study, giving up earlier than predicted is in most cases not likely to be a result of a progressive reduction in the association between the waiting behaviour and the expected reward, because successful food exchanges occurred before and after renouncement to wait. When coping with longer delays, Goffins showed idiosyncratic behavioural patterns, which could serve to self-distract themselves from eating the food before being able to exchange. Similar behaviours were found in previous studies on chimpanzees and human children: most chimpanzees, tested in an accumulative *DGT*, were able to endure longer delays when they could distract themselves by manipulating toys (Evans & Beran, 2007). Children at the age of four years, that were given toys or were cued to think about funny things during the delay duration, waited significantly longer to obtain a highly preferred reward (up to 15 minutes) than children that were animated to just think about the reward (under 30 seconds) (Mischel et al., 1972). Additionally children that showed spontaneous behaviours that aim to avoid looking at the reward or distract their thoughts away, like e.g. covering the eyes with the hands, talking, singing songs, playing with their hands etc., were more successful in delaying gratification than other (Mischel et al., 1989).

Although Goffins initially exchanged at higher rates than corvids, their longest waiting times did not exceed 80s, while some corvids waited more than five minutes (Dufour et al., 2011). Goffins exhibited a low inhibitory threshold for depositing the initial item onto the table before exchange opportunities. They rarely did and almost immediately picked it up again, while crows and ravens temporarily discarded the initial food item in all delays over 20s (Dufour et al., 2011). Hence, food hoarding species may have an advantage over non-hoarders in exchange tasks in respect to the fact that they 'can let go' and do not have to hold on the initial item in the beak, close to their taste organs, throughout the entire delay. Furthermore, Goffins were tested on a plain experimental table and corvids in an aviary compartment, which had more enriching landscape characteristics. This may have distracted subjects during waiting (Evans & Beran, 2007) and subjects had the possibility of placing the initial item out of their sight during the delay. However, the overall performance of Goffins indicates that food caching is not a precondition for birds to evolve mechanisms for coping with a delayed gratification.

Unlike carrion crows of which only three exchanged at very low rates (0.93%, 4.63%, 12.03%) and only at the 2s delay in *quantitative DGTs* (Wascher et al., 2012), eight out of 14 Goffin cockatoos still exchanged for up to 20s and one at high rates until 10s delays. Overall exchange rates were higher than those of the carrion crows. However, Goffins' exchange rates were much lower in *DQN* than *DQL*, fitting the assumption that birds tend to show more impulse control for maximizing quality than quantity. There are two potential explanations for this behavior: either a failure to attribute quantity the same value as quality as being worth waiting for (Wascher et al., 2012), or the rewards used in quantitative tasks in avian studies were too delectable to inhibit consummation: a highly favored reward was used in both, corvids (cheese) and Goffins (cashew nut). Future studies on *quantitative DGTs* should thus incorporate several reward types. Another topic for further studies could be to compare the performance of *exchange DGTs* in a plain environment to an enriched one. In chimpanzees, providing inedible toys as distractive objects, prolonged their ability to delay gratification significantly (Evans & Beran, 2007).

In summary, for the first time high levels of impulse control were found in a parrot species in *delayed gratification tasks*. Goffins cockatoos were not only able to wait for gains in quality but also, to some extent quantity. These findings suggest that an extended temporal horizon for decisions concerning food may have evolved convergently within birds (corvids and parrots) and between birds and primates (Dufour et al., 2011).

7. Acknowledgements

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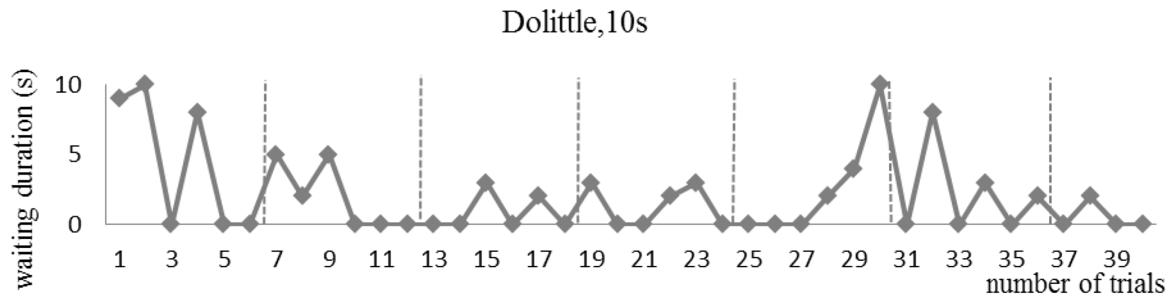
8. References

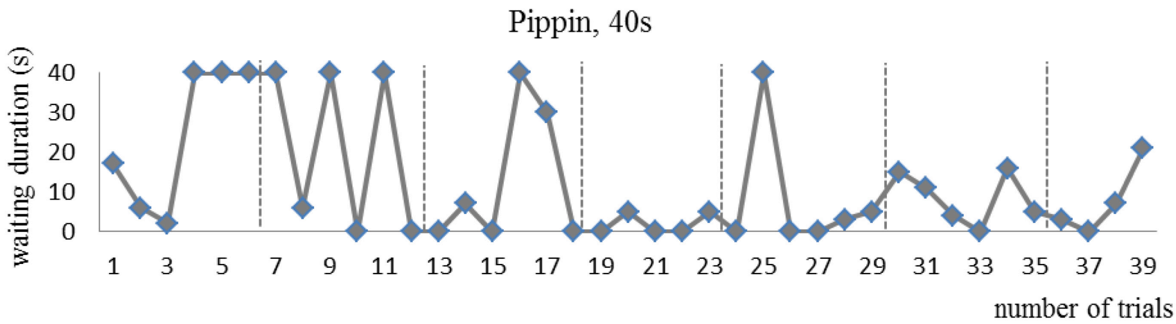
- Abeyesinghe, S. M., Nicol, C. J., Hartnell, S. J., Wathes, C. M. 2005 Can domestic fowl, *Gallus gallus domesticus,* show self-control? *Anim Behav* 70*,* 1–11.
- Addessi, E., Paglieri, F., Focaroli, V. 2011 The ecological rationality of delay tolerance: Insights from capuchin monkeys. *Cognition 119, 142-147*
- Ainslie, G. 1974 Impulse control in pigeons. *J Exp Anal Behav* 21, 485–489.
- Beran, M. J. 2002 Maintenance of self-imposed delay of gratification by four chimpanzees (*Pan troglodytes*) and an orangutan (*Pongo pygmaeus*). *J Gen Psychol* 129(1), 49-66.
- Bramlett, J. L., Perdue, B. M., Evans, T. A, Beran, M. J. 2012 Capuchin monkeys (*Cebus apella*) let lesser rewards pass them by to get better rewards. *Anim Cogn* 15, 963-969
- Cahyadin, Y. Jepson, P., Manoppo, B. I. 1994 *The status of Cacatua goffini and Eos reticulata on the Tanimbar islands*. PHPA/Bird Life International Laporan No. 1. delay. *J Exp Anal Behav* 55, 233–244.
- Dufour, V., Pelé, M., Sterck, E. H. M., Thierry, B. 2007 Chimpanzee (*Pan troglodytes*) anticipation of food return: Coping with waiting time in an exchange task. *J Compa Psych*, 121 (2), 145-155.
- Dufour, V., Wascher, C. A. F., Braun, A., Miller, R., Bugnyar, T. 2011 Corvids can decide if a future exchange is worth waiting for. *Biol Lett* 8(2), 201-204.
- Emery, N. J. 2006 Cognitive ornithology: the evolution of avian intelligence. *Phil Trans R Soc B* 361, 23-43.
- Evans, T. A., Beran, M. J. 2007 Chimpanzees use self-distraction to cope with impulsivity. *Biol Lett* 3, 599–602 .
- Green, L., Estle, S. J. 2003 Preference reversals with food and water reinforcers in rats. *J Exp Anal Behav* 79, 233-242.
- Hayden, B. Y., Platt, M. L. 2007 Animal Cognition: Great apes wait for grapes. *Curr Bio* 17, 21, 922
- Hidetoshi, A., Ai, K., Toshiya, M. 2010 Social influence of competition on impulsive choices in domestic chicks. *Biol Lett* 6, 183-186.
- Leonardi, R. J., Vick, S.-J., Dufour, V. 2012 Waiting for more: the performance of domestic dogs (*Canis familiaris*) on exchange tasks. *Anim Cogn* 15, 107-120.

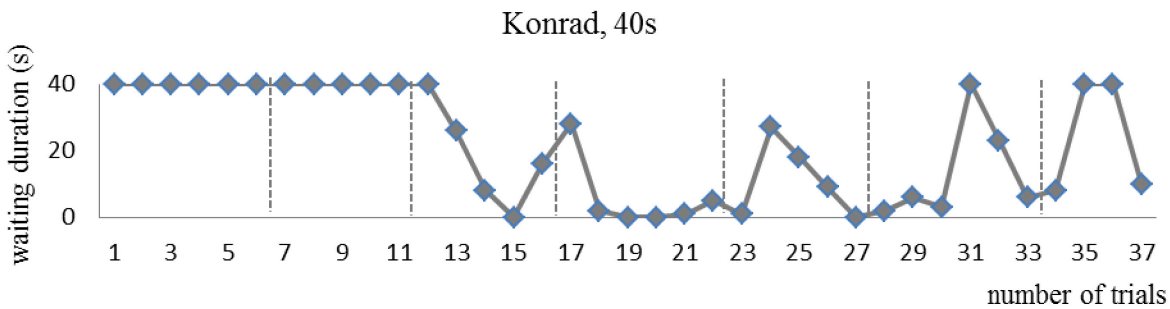
- Mischel, W., Shoda ,Y., Rodriguez, M. L. 1989 Delay of gratification in children. *Science* 244, 933-938.
- Mischel, W., Ebbesen, E. B. & Zeiss, A. R. 1972 Cognitive and attentional mechanisms in delay of gratification. *J. Pers. Soc. Psychol.* 21, 204–218.
- Murray, E. A., Kralik, J. D., Wise, S. P. 2005 Learning to inhibit prepotent responses: successful performance by rhesus macaques, Macaca mulatta, on the reversed-contingency task. Animal Behaviour 69, 991-998.
- Pelé M., Dufour V., Micheletta J., Thierry B. 2010 Long-tailed macaques display unexpected waiting abilities in exchange tasks. *Animal Cognition* 13, 263-271.
- Pelé M., Micheletta J., Uhlrich P., Thierry B., Dufour V. 2011 Delay maintenance in tonkean macaques (*Macaca tonkeana*) and brown capuchin monkeys (*Cebus apella)*. *International Journal of Primatology* 32(1), 149-166.
- Rachlin, H., Raineri, A., Cross, D. 1991 Subjective probability and delay. *J Exp Anal Behav* **55,** 233–244.
- Ramseyer, A., Pelé, M., Dufour, V., Chauvin C., Thierry B. 2006 Accepting loss: the temporal limits of reciprocity in brown capuchin monkeys. *Proc R Soc B* 273, 179-184.
- Rosati, A. G., Stevens, J. R., Hare B., Hauser, M. D. 2007 The evolutionary origins of human patience: temporal preferences in chimpanzees, bonobos and human adults. *Curr Bio* 17, 1663-1668.
- Stephens, D.W., Kerr, B., Fernandez-Juricic, E., 2004. Impulsiveness without discounting: the ecological rationality hypothesis. *Proc. R. Soc. Lond. B; Biol. Sci.* 271, 2459–2465
- Stevens, J. R., Hallinan, E. V., Hauser, M. D. 2005 The ecology and evolution of patience in two New World monkeys. *Biol Lett*, 1, 223-226.
- Vick, S.-J., Bovet D., Anderson J. R. 2009 How do African grey parrots (*Psittacus erithacus*) perform on a delay of gratification task? A*nim Cog* 13 (2), 351-358.
- Wascher, C. A. F., Dufour, V., Bugnyar, T. 2012 Carrion crows cannot overcome impulsive choice in a quantitative exchange task. *Front Comp Psych* 3,118.

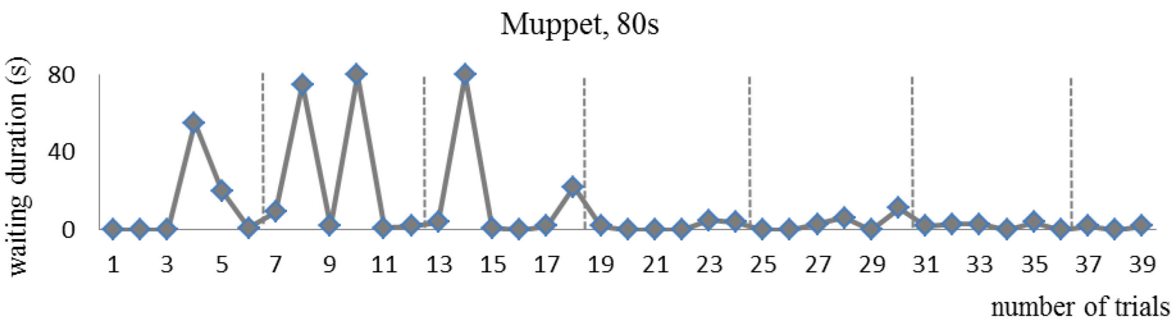
9. Appendix

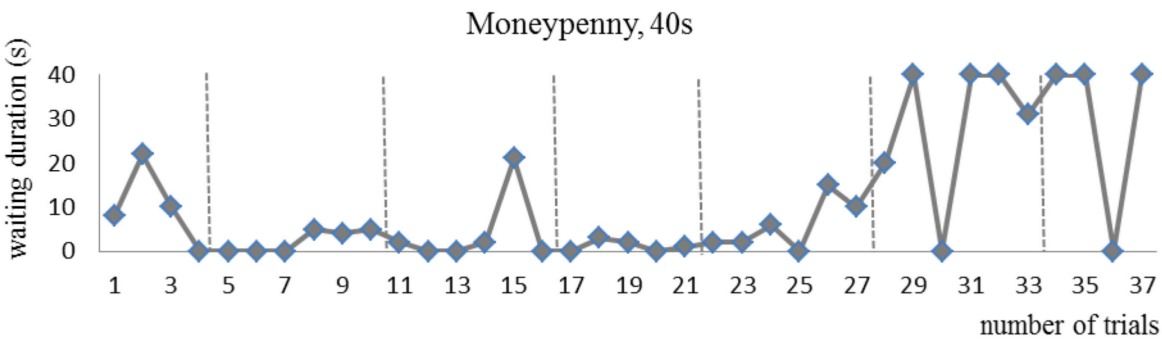
Waiting duration per trial at the last delay in which subjects successfully exchanged at least one time (*DQL*).

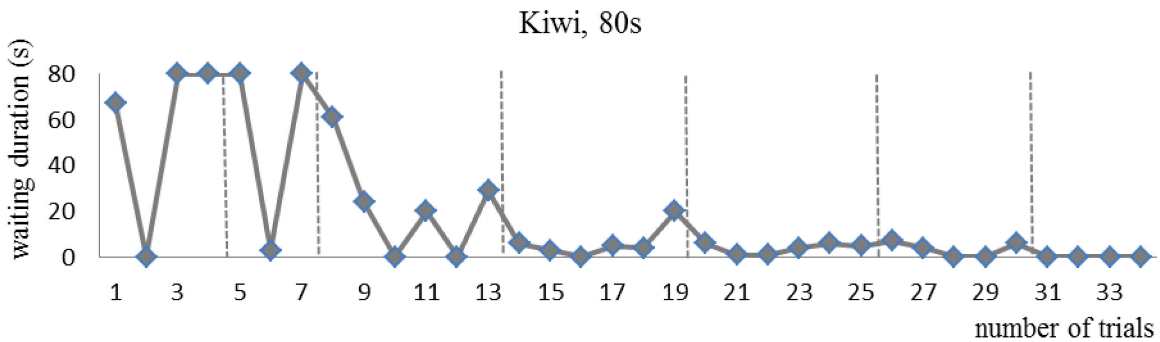


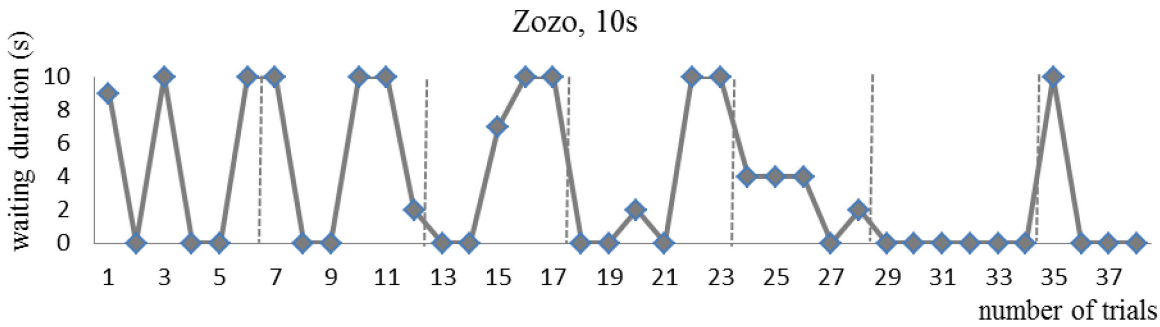


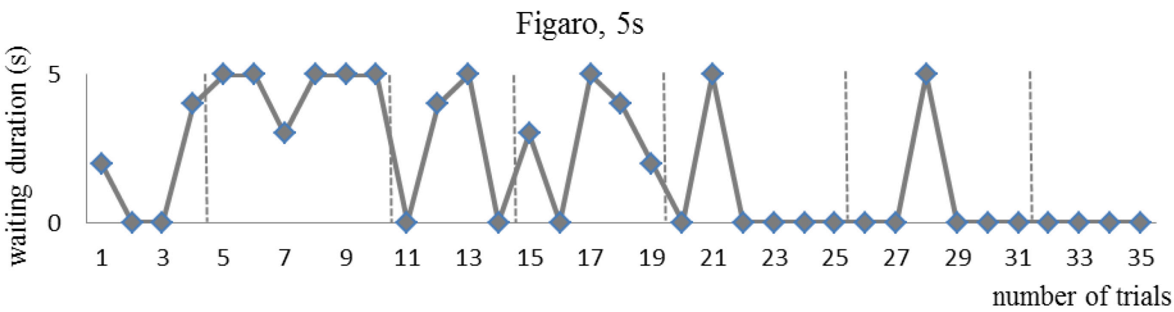


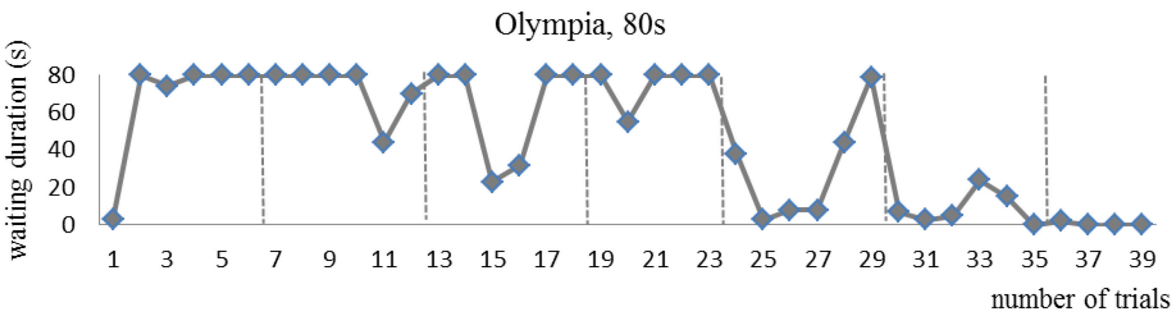


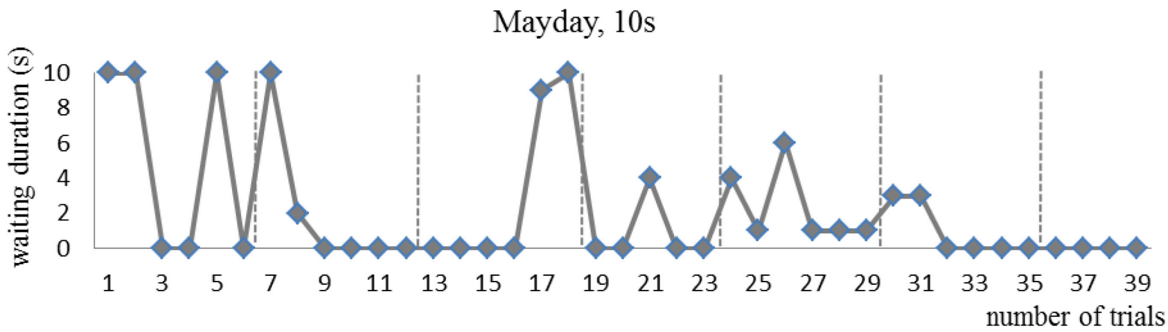

Moneypenny, 40s
waiting duration (s)
number of trials

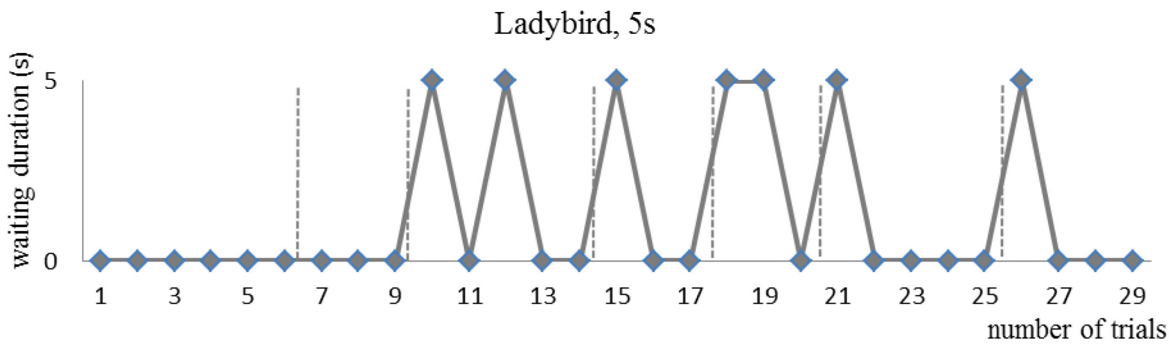

Kiwi, 80s
waiting duration (s)
number of trials

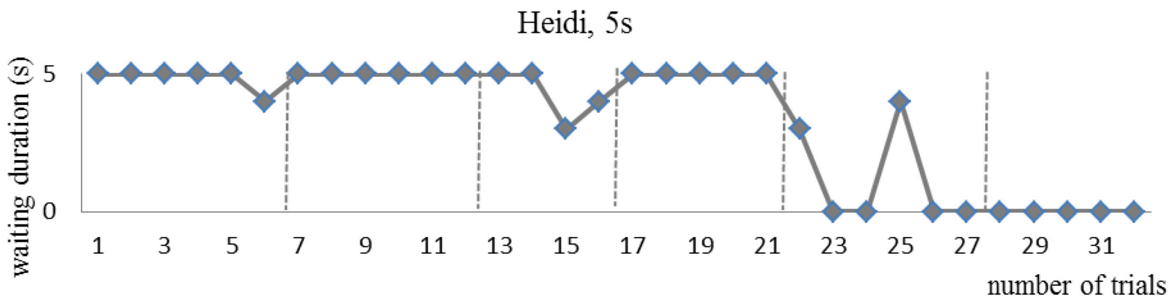

Zozo, 10s
waiting duration (s)
number of trials

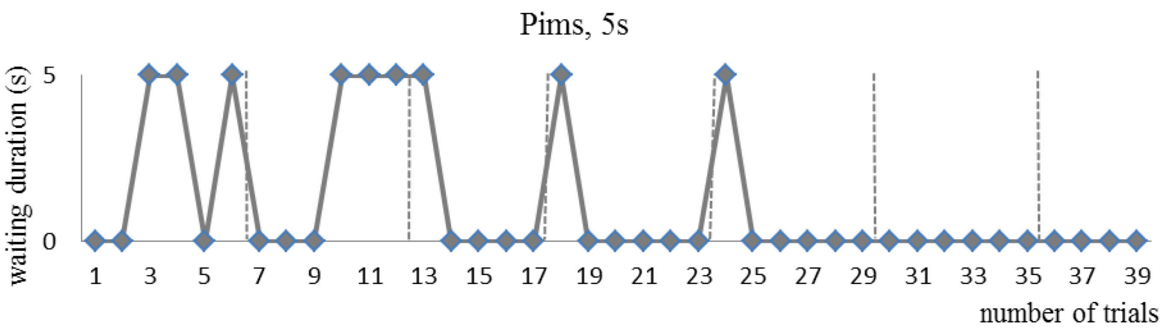

Figaro, 5s
waiting duration (s)
number of trials


Olympia, 80s
waiting duration (s)
number of trials


Mayday, 10s
waiting duration (s)
number of trials


Ladybird, 5s
waiting duration (s)
number of trials


Heidi, 5s
waiting duration (s)
number of trials


Pims, 5s
waiting duration (s)
number of trials

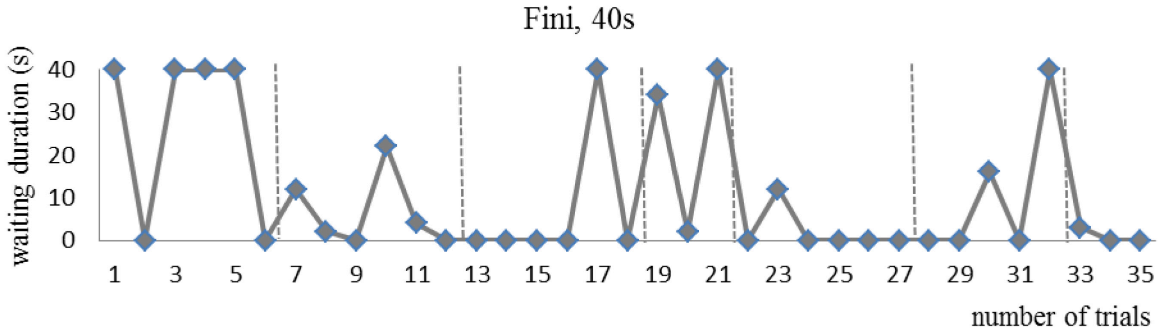
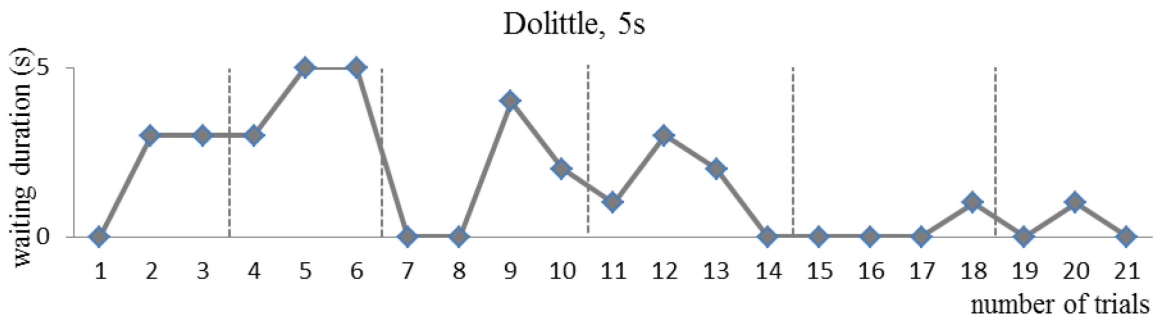
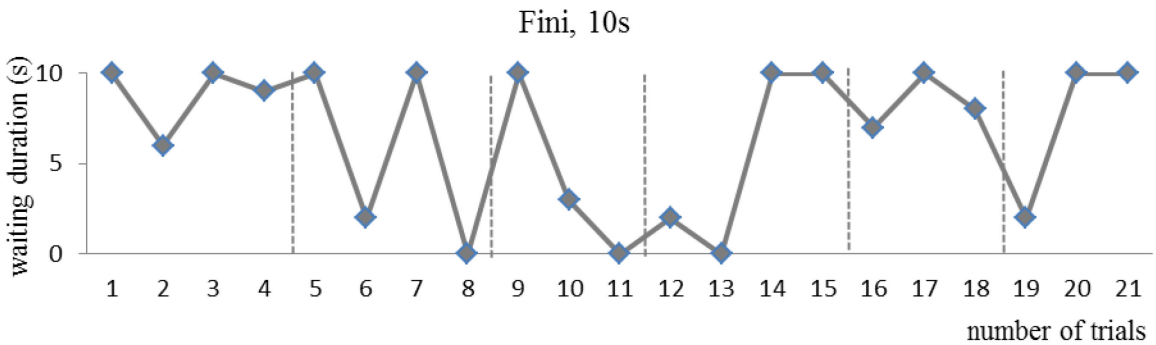
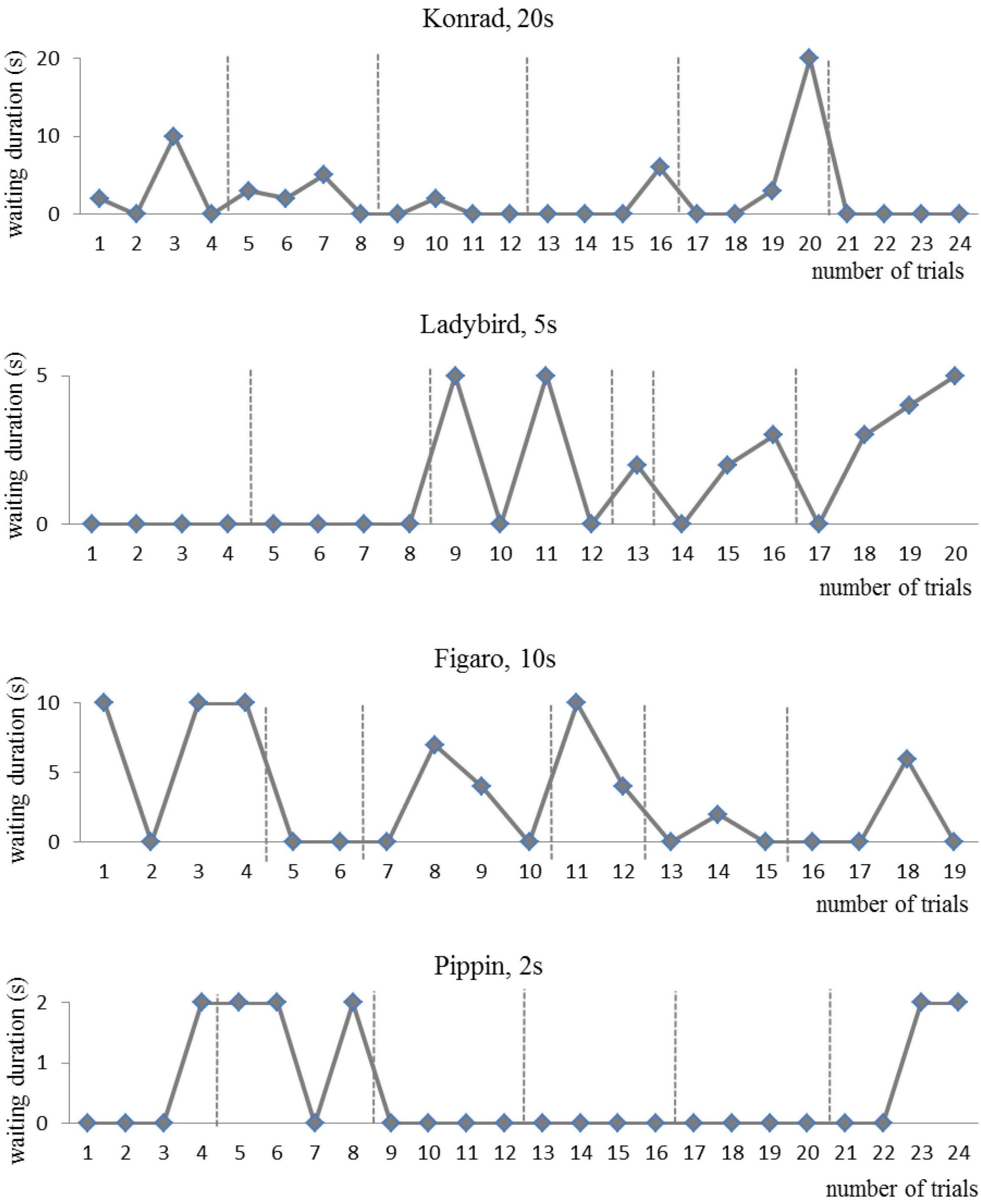


Figure 8. Waiting duration per trial at the last delay in which subjects successfully exchanged at least one time (*DQL*). Vertical, dashed lines mark one session (a maximum of one session per day was conducted, see 4.1). Successful exchanges mostly occurred neither exclusively in the first trials of a session, nor solely in the first trials of a stage. In many cases (e.g. Konrad, Moneypenny, Zozo, Figaro, Pims, Ladybird, Fini) renouncement to wait cannot be explained by a gradually extinction of the waiting behavior. Although subjects renounced waiting in several trials, they subsequently decided to wait again for the whole duration of the delay to obtain the preferred food reward.

Waiting duration per trial at the last delay in which subjects successfully exchanged at least one time (*DQN*).






Konrad, 20s
waiting duration (s)
number of trials
Ladybird, 5s
waiting duration (s)
number of trials
Figaro, 10s
waiting duration (s)
number of trials
Pippin, 2s
waiting duration (s)
number of trials

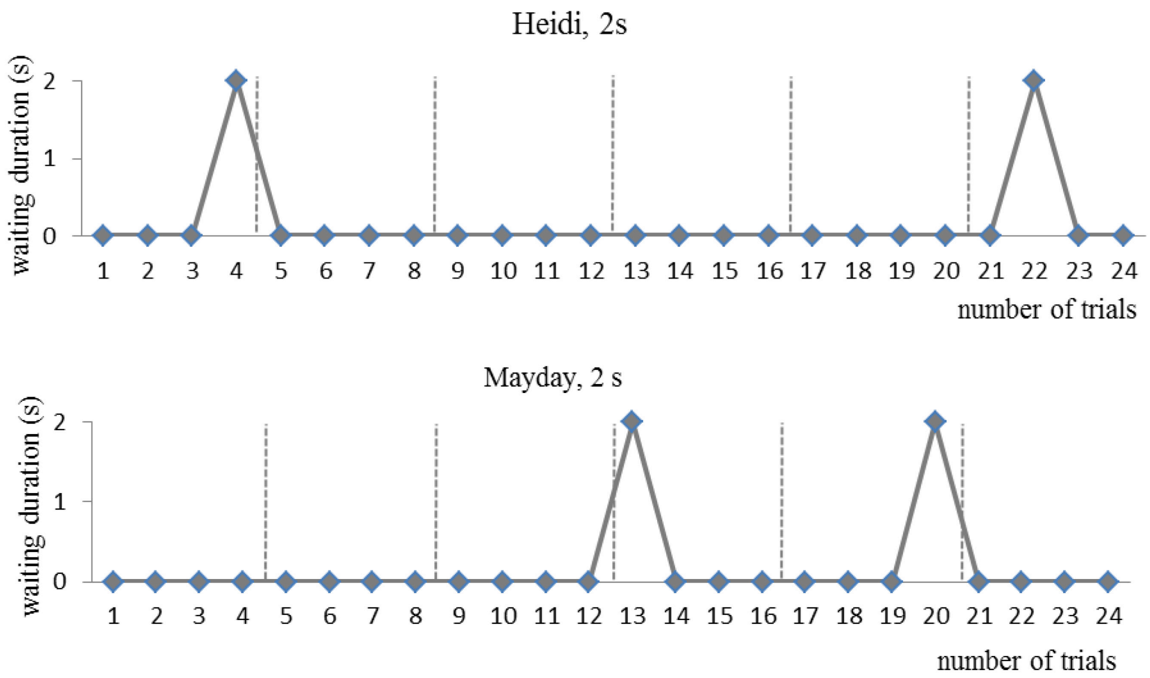


Figure 9. Waiting duration per trial at the last delay in which subjects (n=8) successfully exchanged at least one time (*DQN*). Vertical, dashed lines mark one session (a maximum of one session per day was conducted, see 4.1). Successful exchanges mostly occurred neither exclusively in the first trials of a session, nor solely in the first trials of a stage. In most cases (e.g. Fini, Heidi, Konrad, Ladybird, Mayday, Pippin) renouncement to wait cannot be explained by a gradually extinction of the waiting behavior. Although subjects renounced waiting in several trials, they subsequently decided to wait again for the whole duration of the delay to maximize quantity.

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