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MASTERARBEIT / MASTER’S THESIS

Titel der Masterarbeit / Title of the Master‘s Thesis

Assessing Azure-winged magpies’ (*Cyanopica cyanus*) responses to mirrors

verfasst von / submitted by

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

Master of Science (MSc)

Wien, 2019 / Vienna, 2019

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	A 066 878
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Verhaltens-, Neuro- und Kognitionsbiologie UG2002
Betreut von / Supervisor:	Univ.-Prof. Mag. Dr. Thomas Bugnyar

Acknowledgements

I am grateful to my supervisors, Univ.-Prof. Mag. Dr. Thomas Bugnyar and Lisa-Claire Vanhooland, MSc. for all their help and support and for making it possible for me to conduct this study. Furthermore, I would like to thank András Péter, MSc. for building the apparatus for the experiments and the staff of the Animal Care Facility of the Department of Cognitive Biology for taking such good care of our birds. I am also grateful to my family for the moral and financial support throughout my studies. Last but not least, many thanks to my partner, Martin Labuta, MSc., for giving me all the help and support, one can possibly get.

Abstract

Mirror self-recognition (MSR) has commonly been tested with the Mirror-Mark test and used as an indicator for having a concept of self. Typically, animals show a similar string of behaviours when responding to mirrors, namely social reactions and explorative behaviours, followed by contingent behaviour and in some species, self-directed behaviour. Species that pass the mark test (i.e. apes, elephants, dolphins, magpies) commonly share characteristics when it comes to living in complex social systems, possessing advanced cognitive skills and a high encephalization index. Corvids have further been proven able of perspective taking, making them likely candidates for MSR. The azure-winged magpie (*Cyanopica cyanus*), a cooperatively breeding corvid species, is particularly interesting to study in this aspect due to its prosocial tendencies and social system. Therefore, in the present study we exposed 10 azure-winged magpies to mirrors and non-reflective surfaces and measured their responses before conducting a Mirror-Mark test. Our methods slightly differed from those used with other Corvids, namely that birds were tested in their home aviaries and we used pairwise, group and individual exposures. Using different types of exposures allowed us to assess, which one was better suitable to test this species. Birds tended to spend more time in front of the apparatus and show startle behaviours less frequently in the group setting compared to the pairwise exposures, however this difference was not significant. None of the birds showed any behaviour indicating mirror self-recognition throughout the whole exposure. They further failed to exhibit mark-directed behaviours in the subsequent Mark Test. Behaviours of all four categories were exhibited at some point of the exposure and are comparable to those shown in other species. However, the string of behaviours in front of the mirror did not follow the expected pattern and overall, birds did not prefer the mirror over the controls. These results are surprising considering the positive results with Eurasian magpies, however it is in line with other studies on Corvids which failed to replicate those results.

Zusammenfassung

Selbsterkennung im Spiegel wird meistens mit dem Spiegeltest getestet und als Indikator für Selbstbewusstsein/Ich-Bewusstsein in Tieren verwendet. Typischerweise zeigen Tiere die gleiche Reihe von aufeinanderfolgenden Verhaltensweisen, wenn sie mit einem Spiegel konfrontiert werden, angefangen mit sozialen Reaktionen und Spiegelerkundung, gefolgt von Verhaltensweisen, welche die Beziehung zwischen Realität und Spiegelbild untersuchen und bei einigen Arten selbstgerichtetem Verhalten. Arten, die den Markentest bestehen (z. B. Affen, Elefanten, Delfine und Elstern), teilen bestimmte Eigenschaften; sie leben in komplexen sozialen Systemen, besitzen fortgeschrittene kognitive Fähigkeiten und verfügen über einen hohen Enzephalisationsquotient. Korviden sind fähig, die Perspektive von Artgenossen zu verstehen, wenn sie ihr Futter verstecken und haben daher eine hohe Wahrscheinlichkeit, Fähigkeiten zur Selbstwahrnehmung an den Tag zu legen. Blauelstern (Cyanopica cyanus) sind eine kooperativ brütende Korvidenart, die aufgrund ihrer prosozialen Tendenzen und ihres Sozialsystems in diesem Aspekt besonders interessant zu untersuchen sind. Daher haben wir in dieser Studie 10 Blauelstern mit Spiegeln und nicht reflektierenden Oberflächen konfrontiert und ihre Reaktionen gemessen, bevor wir einen Mirror-Mark-Test durchgeführt haben. Unsere Methoden unterschieden sich leicht von anderen Studien mit Korviden, nämlich, dass die Vögel in ihren Heimvolieren einzeln, im Paar und in Gruppen getestet wurden. Durch die Verwendung dieser verschiedenen Methoden konnten wir beurteilen, welche für diese Art besser geeignet war. In der Gruppe neigten Vögel dazu, mehr Zeit vor dem Apparat zu verbringen und weniger häufig Schreckverhalten zu zeigen als im Paar, jedoch war dieser Unterschied nicht signifikant. Keiner der Vögel zeigte während des Experiments Verhaltensweisen, die auf Selbsterkennung im Spiegel hinweisen würden. Verhaltensweisen aller vier Kategorien waren zu beobachten, vergleichbar mit denen, die bei anderen Arten gefunden wurden. Die Reihe der Verhaltensweisen vor dem Spiegel entsprach nicht dem erwarteten Muster, und insgesamt haben die Vögel keine Präferenz für den Spiegel gezeigt. Diese Ergebnisse sind angesichts der positiven Ergebnisse bei eurasischen Elstern überraschend, sie stimmen jedoch mit anderen Studien an Korviden überein, die diese Ergebnisse nicht replizieren konnten.

Assessing Azure-winged magpies' (*Cyanopica cyanus*) responses to mirrors

Introduction

Recognizing one's own image in the mirror requires a sense of self and has therefore been suggested to be an indicator of self-awareness (Gallup, 1979). Animals that are capable of self-awareness could also potentially use this experience to understand mental states in others – known as mental state attribution or theory of mind (Gallup, 1982). This indicates, that species which recognize themselves in a mirror, can take into account what others know, want or intend to do. For instance, it has been shown in 18-24 months old children, that mirror-self recognition is positively correlated with altruistic and prosocial behaviour (Johnson, 1982). Since the concept of mental state attribution was first introduced by Premack & Woodruff (1978), it has become an important measure to assess the possible similarities between the human and animal mind. As mentioned above, mirror-self recognition could be an important – even though not crucial - step towards theory of mind, which makes it interesting to study in different animal species.

Mirror self-recognition has been experimentally tested for the first time in chimpanzees and several species of monkeys (Gallup, 1970). First, subjects were confronted with a mirror for 10 days and their behaviour was observed. Initially, they reacted as if there was another chimpanzee in the mirror and showed social displays towards their reflection. However, after a few days, these social responses diminished, and animals started to exhibit self-directed behaviours such as grooming body parts which would be invisible without the mirror. To assess the possibility that chimpanzees might be able to recognize themselves in the mirror, Gallup devised the mark test. Subjects were anesthetized and provided with an odourless red mark on one of the eyebrows and the top half of the opposite ear. After recovery, observations in the presence and in the absence of a mirror were conducted. Without the mirror, chimpanzees rarely touched the mark, which proved, that they are not aware of it. With the mirror, however, they used their reflection to touch the mark and even smelled their fingers after touching the marked areas. Using a control group consisting of chimpanzees without prior experience with mirrors, Gallup showed that mark-directed responses are limited to subjects who have been confronted with mirrors before the mark test. He conducted the same experiment with three species of monkeys: stumptailed, rhesus, and cynomolgus macaques.

Their initial reaction to the reflection was similar to that of chimpanzees, but even after prolonged exposure, they did not show any self-directed behaviour using the mirror. This finding indicates, that there might have been a divergent evolution of this trait between apes and monkeys.

Since this pioneering study, researchers have been trying to assess if the ability of mirror self-recognition is present in other species as well. Gordon Gallup´s seminal study (Gallup, 1970) has been successfully replicated with many chimpanzees in different settings (e.g., Calhoun & Thompson, 1988; Lethmate & Dücker, 1973; Lin, Bard, & Anderson, 1992) and in orang-utans (Lethmate & Dücker, 1973; Suarez & Gallup, 1981), but in case of gorillas, there is only one report about self-recognition in a human-reared gorilla (Patterson & Cohn, 1994). Other studies failed to find any evidence of self-recognition in this species (e.g., Ledbetter & Basen, 1982; Suarez & Gallup, 1981). One possible explanation could be that mirror self-recognition in gorillas relies more strongly on individual experience and personality as for instance sign-language training and rearing amongst humans seems to facilitate self-recognition (Povinelli, 1994). Another interesting hypothesis comes from Gallup (1997), who suggests that the ability for self-recognition might be disappearing in gorillas due to evolutionary changes in their socio-ecology. Individual differences could indeed account for differences in the ability for mirror self-recognition as even in chimpanzees, not every individual passes the Mark test: about 75 % of young adults are successful and this result declines in young and aging individuals (Povinelli et al., 1993). A few findings in other species, such as dolphins (Reiss & Marino, 2001), elephants (Plotnik, de Waal & Reiss, 2006), magpies (Prior et al., 2008), cleaner wrasses (Kohda et al., 2019) and ants (Cammaerts and Caemmaerts, 2015) suggest, that the ability for self-recognition might not be limited to primates, although none of these studies – except for the one on dolphins (Morrison & Reiss, 2018) – has been successfully replicated and their results are debated (Gallup & Anderson, 2018).

These findings and the evidence of mirror-self recognition in different species show, that this trait might have evolved through convergent evolution in various taxa and can be observed in species with complex social understanding and advanced cognitive skills (Plotnik, de Waal & Reiss, 2006).

Since Gallup’s first study on chimpanzees (Gallup, 1970), many different species have been tested for mirror self-recognition. Interestingly, these species show a similar string of behaviours in front of the mirror, which consists of initial social behaviours followed by exploratory and contingent behaviours and in case of only a few species, self-directed behaviours.

If mirror self-recognition is an indicator of mental state attribution, species with the ability to recognize themselves in a mirror, should be able to understand the mental states of others and therefore, they should be able to “feel” for others, thus showing for instance sympathy and empathy (Gallup, 1982). This hypothesis can be also confirmed by the fact that young children seem to take into account how others feel only when they are old enough to recognize themselves in a mirror (Carruthers & Smith, 1996). Moreover, consolation behaviour, which can be considered an indicator of some sort of empathy, is present in apes but largely absent in monkeys (de Waal 1996, 2003). This finding could serve as a possible explanation as to why mirror self-recognition can be found in apes but not in monkeys. Corvids, a family of food-storing birds, are characterized by a high relative brain size compared to their body weight (Iwaniuk et al., 2005) and show similarly complex cognitive abilities to primates (Emery & Clayton, 2004; Bugnyar, 2011). Living in complex social groups and being able to cache and retrieve food by taking into account the social setting likely resulted in a high level of social intelligence in these species (Prior, Gonzalez-Platta & Güntürkün, 2004). For instance, food-storing birds cache food regularly and are not only able to remember the time and location of the event (Clayton & Dickinson, 1999), but also conspecifics, who observed them during caching (Dally, Emery & Clayton, 2006). Furthermore, ravens have been shown to differentiate between observers who could potentially see the caching event and conspecifics, whose view has been blocked by a barrier (Bugnyar & Heinrich, 2005). This instance of perspective taking could be an indicator of theory of mind in this species, which could suggest that Corvids might be able to recognize themselves in mirrors as well.

Cooperatively breeding species are particularly interesting to study in this aspect since according to the cooperative breeding hypothesis, living under these social conditions could favour prosocial behaviour. Azure-winged magpies are colonial cooperative breeders living in large flocks, which contain several small family units (Cramp, 1994). This species maintains a flexible helping system where both related and unrelated group members can be helpers (Komeda et al., 1987), which requires individuals to take into account the needs of others. They have been found to produce results consistent with the cooperative breeding theory in a prosocial task (Horn et al., 2016), which could support the suggested link between prosociality and empathetic behaviour (Eisenberg, Eggum & Di Giunta, 2010).

To date, there is only one study with Corvids, showing mirror self-recognition in 2 out of 5 magpies (Prior et al., 2008). Other studies failed to replicate these results in several different corvid species - e.g. jackdaws (Soler, Pérez-Contreras & Peralta-Sánchez, 2014) and Carrion crows (Vanhooland et al. (in press)). In the light of the existing literature it would be interesting to see, if other species from the corvid family are also capable of mirror self-recognition, therefore, in this study, I tested azure-winged magpies (*Cyanopica cyanus*).

I expected to find similar results to those shown by Prior et al. (2008) with Eurasian magpies, namely, that birds would initially show social displays towards their reflection, but this behaviour would be reduced or even absent after prolonged exposure to the mirror. I hypothesized that if azure-winged magpies are capable of mirror self-recognition, they should show enhanced mark-directed behaviour in case of being presented with a mirror in contrast to the controls and wearing a coloured mark should also cause increased interest in the marked area compared to the sham marking.

Methods

Subjects

In this study I worked with ten captive azure-winged magpies (*Cyanopica cyanus*) housed at the Animal Care Facility of the Department of Cognitive Biology at the University of Vienna, Austria. Subjects were kept in two groups in two separate outdoor aviaries (Fig. 1.) in auditory and visual contact with each other: six individuals in the outside group and four in the inside group (Table 1.). Birds had ad-libitum access to food and water throughout the whole experiment. None of the subjects had experience with mirrors prior to this experiment.

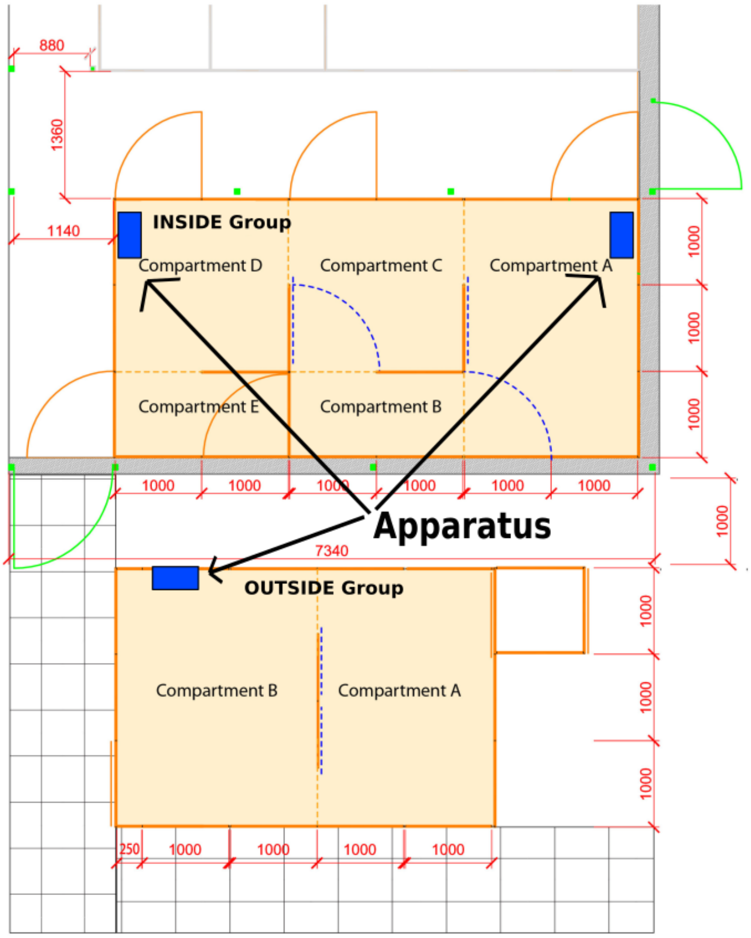

Figure 1: Arrangement of the aviaries and location of the apparatus

Apparatus

The apparatuses were installed in the birds' home aviaries (one for the outside group and two for the inside group – Fig.1) one month prior to the start of the experiments. It consisted of a wooden frame which could hold either a mirror (30 cm x 30 cm), a wooden plate or a plate covered with silver foil of the same dimensions. The apparatuses were installed on the fence of the aviaries 1,5 m above the ground for the inside group and 1,2 m for the outside group. All the apparatuses were provided with branches thus enabling the birds to sit in front of it and go around it (Fig. 2).

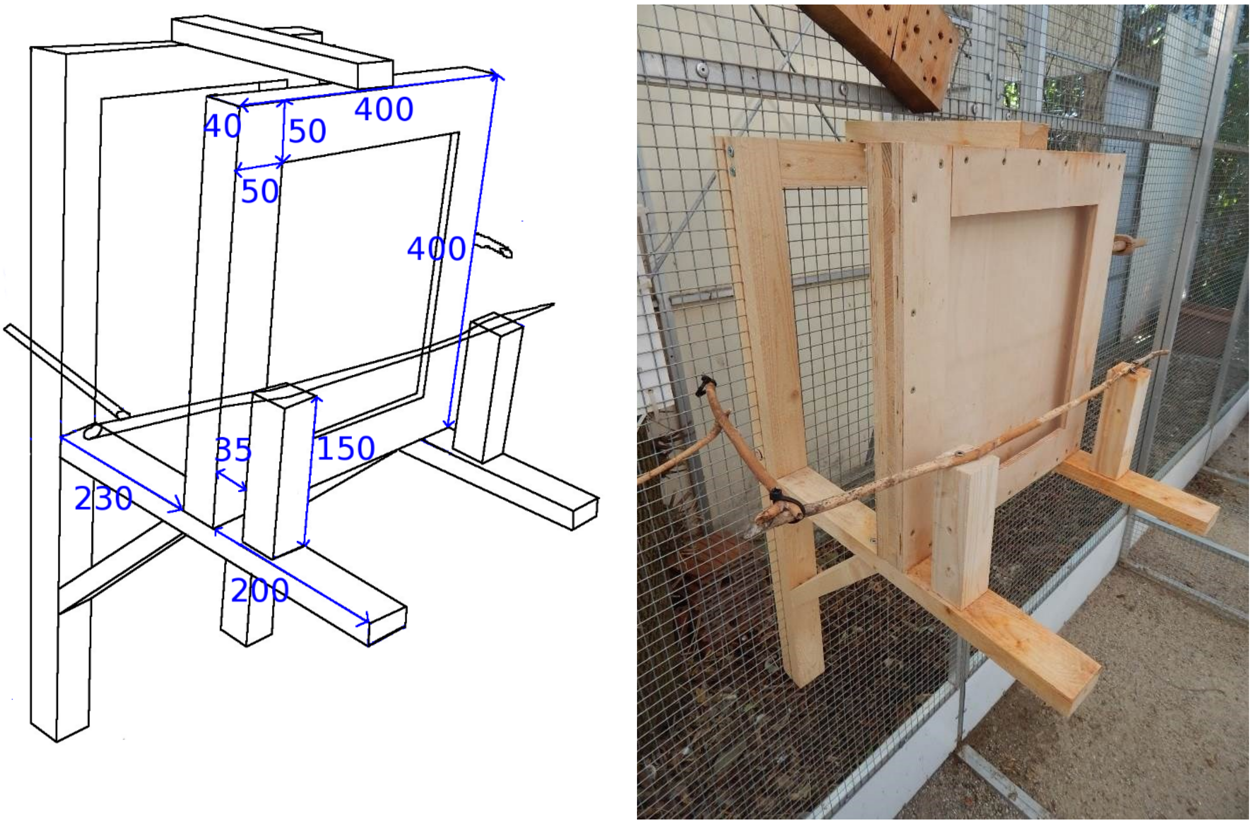

Figure 2: Dimensions of the apparatus

Experimental procedure

Experiments were preceded by a one-month long habituation phase, during which birds were offered mealworms in front of the apparatus three to four times a week. These sessions lasted for 5-10 minutes, during which the apparatus was either empty or the wooden plate was placed into the frame (to avoid habituation to the mirror) until birds took the bait then the plate was removed. These sessions were necessary to get them acquainted not only with the apparatus but also with the plate being moved in and out of it and to reduce neophobic reactions.

Procedure Outside Group

The experiment consisted of two main parts: first, a mirror-image stimulation phase to get the birds acquainted with the mirror, followed by a mark test.

During the *mirror-image stimulation phase*, subjects were exposed to either a mirror, a wooden plate or a plate covered in silver foil (both non-reflective controls) in their home cages first with conspecifics (group exposure), later separated from conspecifics (individual exposure). During the group exposure, birds took part in two sessions in each condition in a randomized order for a total of two hours per condition.

In the *individual exposure*, each bird received at least 5 sets of sessions but a maximum of 15 sets. One set consisted of two mirror-sessions, one wood-session and one session with the plate covered in foil. Each bird was tested once a day and 3-4 times a week. Subjects were separated individually in the compartment were the apparatus was located. At the beginning of each session, two mealworms were placed on the apparatus which the tested bird could take within one visit. Each session lasted 20 minutes during which the individuals could freely move around the compartment and approach the apparatus at will. The order of sessions was randomized within sets and over subjects. To take part in the mark test, birds had to spend at least a cumulative time of 10 minutes in front of the mirror. If the birds did not seem scared of the apparatus in the different conditions after completing the maximum of 15 sets, they moved to the Mark test even if they did not reach the 10 minutes criterion. Three birds reached the 10 minutes criterion (Anakin completed 5 sets, Rey and Chewie 12 sets), the other three individuals received the maximum of 15 sets of sessions.

Mark test

The Mark test was preceded by a training phase during which birds were rewarded for coming to the fence where they were touched with a brush on the throat and the belly. Before each test session, the tested subject was marked on the throat with a brush (Fig. 3.), the tip of which was always coloured, whether the sham mark or the coloured mark was applied. Birds were marked either with pure glycerine (sham mark) or glycerine mixed with food colouring (mark) and individually exposed to a mirror, a non-reflective wooden plate or a plate covered in silver foil. Each bird received 2 rounds of 20 minutes long sessions in each of the following 6 conditions: mirror-mark, mirror-sham, wood-mark, wood-sham, foil-mark, and foil-sham. The order of exposure to these conditions within each round was randomized over subjects.

Figure 3. Position of the mark

Post-mark behaviour

After each session, the focal bird was followed for an additional 5 minutes after re-joining the group to see if the mark resulted in the subject being cleaned by the members of the group.

Visible Mark Control

Before and after the mark test, each bird received two additional control sessions: one with a sham and one with a coloured marking on their breast in a counterbalanced order and their reaction was observed for 5 minutes to make sure that subjects are motivated to interact with the mark. Birds were tested either with red or yellow marks depending on their reaction to those colours. (Table 1.).

Procedure Inside Group

Since the members of the inside group were more stressed by human proximity and showed stronger neophobic reactions to the apparatus, they were tested in pairs to reduce stress caused by individual separation. Two apparatuses were installed in different compartments of the aviary, which made separating the birds into pairs easier and the pairwise sessions more consistent, as each pair was tested with the same apparatus throughout the whole exposure. Both pairs were exposed to the different plates for 5 sets, however – contrary to the outside group – there was no notable habituation to the apparatus. Therefore, the mirror was left in the apparatus for four consecutive days to assess if habituation is possible in the group setting by using continuous exposure. Since this proved to be successful, birds changed to group exposure for another 5 sets of sessions (with 3 conditions each) where the plate was left in the apparatus for 2 consecutive days in each condition to facilitate the habituation. On each testing day, two 20 minutes sessions – at least 3 hours apart from each other - were recorded, at similar times of the day. At the beginning of each session, the apparatus was baited with mealworms (2 per individual) which could be taken within one visit. The order of the different conditions was pseudo-randomized: birds were exposed to each plate for two days and afterwards, a different plate was inserted for the next two days. After finishing 2 sets of sessions, Amidala was transferred to a zoo, thus she did not take part in further experiments.

Table 1. Detailed information about the subjects and an overview of the different types of exposures

Name	**Sex**	**Year of birth**	**Hand-raised (Yes/No)**	**Group**	**Types of exposure**	**Mark test (Yes/No)**	**Colour of the mark**
Anakin	m	2015	N	Outside	Group + individual	Y	yellow
BB8	f	2016	Y	Outside	Group + individual	Y	red
Chewie	f	2015	N	Outside	Group + individual	Y	red
Kylo	m	2016	Y	Outside	Group + individual	Y	yellow
Rey	f	2016	Y	Outside	Group + individual	Y	red
Poe	f	2016	Y	Outside	Group + individual	Y	red
Han	m	2014	N	Inside	Pair + group	N	-
Leia	f	2014	N	Inside	Pair + group	N	-
Jabba	m	2015	N	Inside	Pair + group	N	-
Amidala	f	2012	N	Inside	Pair + group	N	-

Data Analysis

Two cameras (Canon Legria HF-G25, Panasonic HC-X909) were used to record the sessions, both placed outside the aviaries. One of them was facing the apparatus, to have a closer look at the behaviours shown in front of the plate. These recordings were later used to assess the frequency and the duration of the behaviours of interest (Table 2.). The other camera recorded from further away, in order to see, what the focal bird is doing, when not in front of the apparatus. The data acquired through coding the videos using Solomon Coder Version beta 17.03.22 (Péter, 2017), was analysed using IBM SPSS Statistics 23.

Behaviours were grouped into four main categories: social behaviours, explorative behaviours, contingent behaviours and self-directed behaviours. Social behaviours were divided into those directed towards the mirror image and those towards conspecifics. Social behaviours towards the mirror image included forward-threat, head-up, tail-lifting, tail-spread, ruffled feathers, attack, begging display, aggressive pecking and threat. Social behaviours towards conspecifics included displacement, allo-feeding, allo-preening, contact sit and begging. Another subcategory included vocalizations such as contact calls, begging calls, soft calls, chattering, alarm calls and mating calls. Explorative behaviours consisted of pecking plate, pecking frame, plate close inspection, frame close inspection, look behind, look under, look down into mirror and jump against mirror. Durations were recorded for plate close inspection and frame close inspection. Contingent behaviours included peekaboo, stretching and fly against mirror. Self-directed behaviours consisted of auto-preening, stretching, beak wipe, scratching, ruffle, shaking, yawning and mark-directed behaviours such as scratching or cleaning the marked area of the body. Durations were recorded for auto-preening and mark-directed behaviours. Before analysing the data, the mean frequency and duration of behaviours was calculated for each individual in the different exposure types. First, behaviours were pooled according to categories and frequencies and durations were compared between the conditions. Then single behaviours relevant for this study were analysed as well.

Table 2. Ethogram used for analysing the recordings

Behaviour	Description
Visiting apparatus	
On top	The bird is on top of the apparatus, on the wooden frame.
Behind	The bird is either behind the plate or sitting on one of the side branches behind.
In front of	The bird is in front of the plate (whole body or the head).
Next to	The bird is sitting next to the apparatus where the front and side branch meet or in front of the frame.
Exploratory behaviours	
Pecking plate	The bird touches the plate with its beak.
Pecking frame	The bird touches the frame with its beak.
Plate close inspection	The bird is in front of the plate and has the plate in its view.
Frame close inspection	The bird is on the apparatus and takes a closer look at the frame without attempting to cache or pilfer, sometimes with tilted head.
Look behind	The bird goes to one of the side branches and turns its head towards the back of the apparatus, sometimes with tilted head - can be preceded or followed by mirror inspection.
Look under	The bird is sitting in front of the plate or the frame and looks downwards below the plate.
Look down into mirror (attempt)	The bird is sitting on top of the apparatus, bends downwards, facing the front, with head bent over the upper edge of the apparatus.
Jump against mirror	The bird jumps on the lower wooden edge of apparatus in front of the plate.
Self-directed behaviours (on the apparatus):	
Auto-preening front	The bird touches its feathers with its beak while sitting in front of the plate (2 bouts are 5 seconds away).
Auto-preening around	The bird touches its feathers with its beak while sitting somewhere on the apparatus except the front.
Stretching front/around	The bird stretches its wings, legs or neck.
Beak wipe front/around	The bird cleans its beak against something.
Scratching front/around	The bird scratches itself with its foot.

Ruffle front/around	The bird ruffles its feathers.
Shake front/around	The bird shakes itself (whole body).
Yawning front/around	The bird opens its beak for 2-3 seconds without vocalizing or feeding.
Mark-directed behaviours	The bird scratches or cleans the marked area of its body.
Social behaviours	
1. Towards mirror image	
Forward-threat	“Leaning towards object of threat with slightly lifted and fluttered folded wings, tail partly spread on both sides” (Cramp & Perrins, 1994); “Bird crouches and makes jabbing pecks with head lowered, plumage ruffled, wings drooped and partly spread, and tail spread” (Harrison, 1983 – as cited in Cramp & Perrins, 1994).
Head-up	The bird takes an upright position with stretched neck, looking upwards (Birkhead, 1991).
Tail-lifting	The bird is standing still and moves the tail up and down.
Tail-spread	The bird spreads its tail feathers on both sides but does not show forward-threat display.
Ruffled feathers	The bird blows up its feathers.
Attack	Jump against the mirror or to the side when preceded by agonistic display (e.g. forward threat).
Begging display	The bird lowers its head, spreads its wings and tail, lifts wings shorty while vocalising.
Aggressive pecking	Pecking the plate during agonistic displays.
Threat	The bird opens the beak for a short time without vocalizing while pecking the plate.
Vocalizations (modified after Sofia Haley – unpubl.)	
Contact calls	“Short calls with ascending pitch and not obviously directed towards anyone in particular, either in response to or with the response of other contact calls.”
Begging calls	“Soft, high-pitched peeping directed towards individual that has food. Often accompanied by following behaviour” and the bird is slightly lifting its wings when vocalizing.
Soft calls	“Soft/quiet calls with range of pitches and durations (including peeping) that are usually not directed towards anyone in particular, but can be in response to other calls.”

Chattering	“Vocalizations with a lot of variation (of pitch, duration, articulation, call type, etc.) going back and forth between 2 or more individuals; can also occur with just one individual in rare cases.”
Alarm call	“Loud, sharp, and harsh series of syllables in response to a threat to the group.”
Mating P	“High-pitched squeaking right before and during intercourse.”
Mating Br	“The bird is looking upwards with “brrrr” vocalization.”
2. Towards conspecific (in front of and around while on the apparatus)	
a) Agonistic	
Displacement	One bird approaches and the other one retreats within two seconds.
REC Displacement	The bird is displaced by another bird.
Peck	One bird pecks another one.
b) Affiliative	
Allo-feeding	One bird is sharing food with another with beak to beak contact.
Allo-preening	One bird is touching the feathers of another one with the beak.
Contact sit	Birds are sitting next to each other in a distance of one body-length.
Begging to conspecific	High-pitched vocalization directed to a conspecific with food. The bird lifts its wings slightly when vocalizing.
Contingent behaviours	
Peekaboo	The bird goes out of sight of the mirror and returns to the mirror within 3 seconds – except if it is a result of being displaced by another bird.
Stretching front	The bird stretches its wings, legs or neck.
Fly against mirror	The bird flies towards the mirror.
Other	
Startle	Sudden wing-flapping usually followed by a backwards jump or by-flight (flying towards mirror and leaving without landing) or any other sudden aversive reaction to the mirror image – could happen in other conditions as well (Medina et al., 2011).
Caching (attempt)	The bird hides or tries to hide food on the apparatus.
Pilfering	The bird retrieves hidden food on the apparatus.

Flip	The bird is sitting on one of the branches of the apparatus and turns around 360 degrees vertically, while holding on to the branch with its legs.
Manipulating object (only in front of the plate)	The bird manipulates objects while sitting in front of the plate.
Manipulating food (only in front of the plate)	The bird is trying to access food or is feeding while sitting in front of apparatus.

Results

Group exposure – Outside group

During the group exposure each bird has visited the mirror at least once, however, half of the group never went in front of the apparatus in the foil condition. Mirror sessions were characterized by two birds monopolizing the apparatus, exhibiting social displays and explorative behaviour. Birds successfully habituated to the apparatus during these initial exposures: startle behaviour occurred only a few times - only in case of the mirror - and time spent in front of the mirror was greatly reduced already during the second mirror session, indicating habituation. On the group level, there were differences in the frequency of visits to the apparatus between conditions (Friedman: $N = 6$; $\chi^2 = 9{,}652$; $df = 2$; $p = 0{,}008$), but post-hoc tests could not find significant differences (Wilcoxon – mirror-foil: $Z = -2{,}201$; adj. p. = 0,084; wood-mirror. $Z = -1{,}782$; adj. $p = 0{,}225$; foil-wood: $Z = -2{,}023$; adj. $p = 0{,}129$). Time spent in front of the plate was not significantly different between conditions (Friedman: $N = 6$; $\chi^2 = 4{,}000$; $df = 2$; $p = 0{,}135$). Social behaviour towards the mirror was shown only by the two birds monopolizing the apparatus and only in the mirror condition, however, social behaviour towards conspecifics occurred in all three conditions – a few occasions of displacement. Vocalizations happened only during the mirror sessions, consisting of soft calls and begging calls (Friedman: $N = 6$; $\chi^2 = 6{,}000$; $df = 2$; $p = 0{,}05$). There was no difference in the duration of explorative behaviours between conditions (Friedman: $N = 6$; $\chi^2 = 4{,}000$; $df = 2$; $p = 0{,}135$) and only a trend could be found when looking at the frequency of these behaviours (Friedman: $N = 6$; $\chi^2 = 5{,}333$; $p = 0{,}069$). However, some of the behaviours in this category significantly differed considering the frequency of occurrence in the different conditions. Birds looked down to the plate while standing on top of the apparatus with differing frequencies depending on the condition (Friedman: $N = 6$; $\chi^2 = 10{,}381$; $df = 2$; $p = 0{,}006$), however, pairwise comparisons did not find significant differences between conditions (Wilcoxon – mirror-foil: Z = -2,207; adj. p = 0,081; wood-mirror: Z = -2,207; adj. p = 0,081; foil-wood: Z = 0; adj. p = 1). The frequency of explorative behaviours towards the frame (Friedman: N = 6; χ^2 = 7,60; df = 2; p = 0,022) and the plate (Friedman: N = 6; χ^2 = 8,273; df = 2; p = 0,016) was significantly different between conditions, however post-hoc comparisons did not find significant differences (Wilcoxon - frame-directed, foil-mirror: adj. p = 1,965; mirror-wood: adj. p = 0,081; wood-foil: adj. p = 1,032; Wilcoxon - plate-directed, foil-mirror: Z = -2,023; adj. p = 0,129; mirror-wood: Z = -1,892; adj. p = 0,174; wood-foil: Z = -2,041; adj. p = 0,123). Contingent behaviour was limited to the mirror sessions (Friedman: N = 6; χ^2 = 6,000; df = 2; p = 0,05). Self-directed behaviours in front of the plate only occurred during exposure to the mirror, although with rather low frequency (Friedman: N = 6; χ^2 = 4,0; df = 2; p = 0,135).

Individual exposure – Outside group

Contrary to the group exposure, startle behaviour happened in all three conditions with a significant difference between the conditions (Friedman: N = 6; χ^2 = 10,800; df = 2; p = 0,005). Birds startled more often during the mirror sessions, however this difference was not significant (Wilcoxon – mirror-foil: Z = -2,201; adj. p = 0,084; wood-mirror: Z = -2,201; adj. p = 0,084. There was no difference in the frequency of startle behaviours between the wood and foil conditions (Wilcoxon – foil-wood: Z = 0; p = 1)). Individuals did not show clear signs of habituation to either of the three plates – time spent in front of the apparatus did not decrease even after prolonged exposure. The duration of visits varied both between individuals and between sessions. There was no significant difference either in the frequency of visits to the front of the apparatus (Friedman: N = 6; χ^2 = 2,333; df = 2; p = 0,311) or the time spent in front of the plate between conditions (Fig. 4; Friedman: N = 6; χ^2 = 2,333; df = 2; p = 0,311). Social behaviours were mostly limited to tail-lifting, tail-spread, ruffled feathers and vocalizations; however, these behaviours were sometimes also shown in the control conditions, thus no significant difference could be found between conditions (Friedman: N = 6; χ^2 = 3,500; df = 2; p = 0,174). Neither the frequency (Friedman: N = 6; χ^2 = 1,000; df = 2; p = 0,607) nor the duration (Friedman: N = 6; χ^2 = 2,333; df = 2; p = 0,311) of explorative behaviours was significantly different between conditions, however some behaviours in this category did show a difference. The frequency of looking down was significantly different between the three conditions (Friedman: N = 6; χ^2 = 8,435; df = 2; p = 0,015), however post-hoc comparisons did not show significant differences (Wilcoxon – mirror-foil: Z = -0,943; adj. p = 1,035; wood-mirror: Z = -2,201; adj. p = 0,084; foil-wood: Z = -2,032; adj. p = 0,126). Pecking the plate (Friedman: N = 6; χ^2 = 6,0; df = 2; p = 0,05) and pecking the frame (Friedman: N = 6; χ^2 = 8,4; df = 2; p = 0,015) differed significantly between conditions. Post-hoc comparisons did not show significant differences either in case of pecking the plate (Wilcoxon – mirror-foil: Z = -0,943; adj. p = 1,035; wood-mirror: Z = -0,365; adj. p = 2,145; foil-wood: Z = -2,032; adj. p = 0,129) or pecking the frame (Wilcoxon – mirror-foil: Z = -2,023; adj. p = 0,129; wood-mirror: Z = -1,753; adj. p = 0,24; foil-wood: Z = -2,023; adj. p = 0,129). Contingent behaviour was only shown during the mirror sessions, thus differing significantly from the control conditions (Friedman: N = 6; χ^2 = 12,000; df = 2; p = 0,002; Wilcoxon – mirror-foil: Z = -2,207; adj. p = 0,054; wood-mirror: Z = -2,207; adj. p = 0,054). The frequency of self-directed behaviours in front of the plate showed no difference between conditions (Friedman: N = 6; χ^2 = 0,087; df = 2; p = 0,957). Anakin represented a particularly “promising” candidate for mirror-self-recognition, as he spent much more time in front of the mirror than any other bird throughout the whole experiment and he was the only one reaching the 10-minutes criterion within 15 mirror sessions. He did not exhibit any social behaviours and started showing contingent behaviours within the first mirror sessions. On one occasion, he preened himself in front of the mirror, but this behaviour was never repeated. Behaviours of all four categories were exhibited at some point during the exposure, however birds showed the expected string of behaviours neither on the group level nor on the individual level (Fig. 5.).

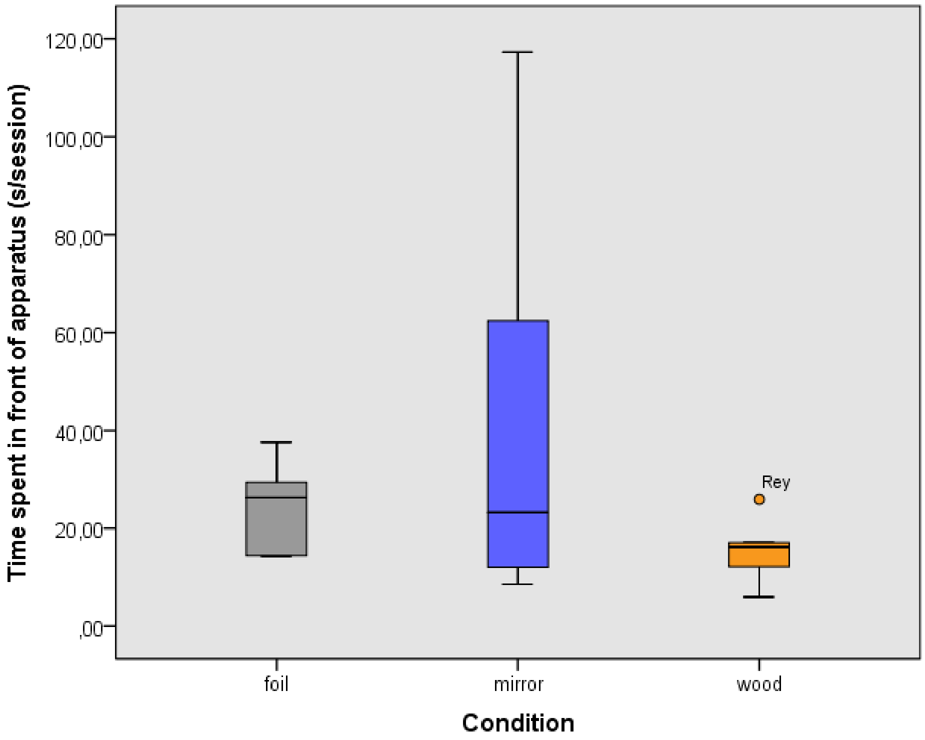

Figure 4. Time spent in front of the apparatus in all three conditions (s/session)
No significant difference could be found between conditions (Friedman: N = 6; $\chi^2 = 2,333$; df = 2; p = 0,311).

Figure 5. Mean frequency of behaviours of the four behavioural categories/minutes spent in front of the mirror
The occurrence of behaviours representing the four categories observed in other species, does not reflect the expected pattern.

Mark Test – Outside group

None of the birds exhibited any kind of mark-directed behaviour throughout the whole exposure. Furthermore, there was no significant difference between the conditions when considering the frequency of visits to the front of the apparatus (Friedman: N = 6; χ^2 = 6,243; df = 5; p = 0,283) or the time spent in front of the plate (Fig. 6.; Friedman: N = 6; χ^2 = 4,808; df = 5; p = 0,440). Startle behaviour did not occur during the Mark Test. Social behaviours were limited to only two cases of vocalizations by the same bird in the mirror-sham and the foil-sham conditions. Birds did not show a difference between the six conditions in the frequency (Friedman: N = 6; χ^2 = 7,969; df = 5; p = 0,158) and the duration (Friedman: N = 6; χ^2 = 6,280; df = 5; p = 0,280) of explorative behaviours directed towards the apparatus. Only one of the birds (Chewie) showed contingent behaviour on one occasion in the mirror-mark condition. Self-directed behaviours in front of the apparatus were limited to only a few occasions and there was no difference in the frequency of occurrence between the conditions (Fig. 7.; Friedman: N = 6; χ^2 = 3,294; df = 5; p = 0,655). Furthermore, birds did not show auto-preening in front of the plate throughout the whole exposure.

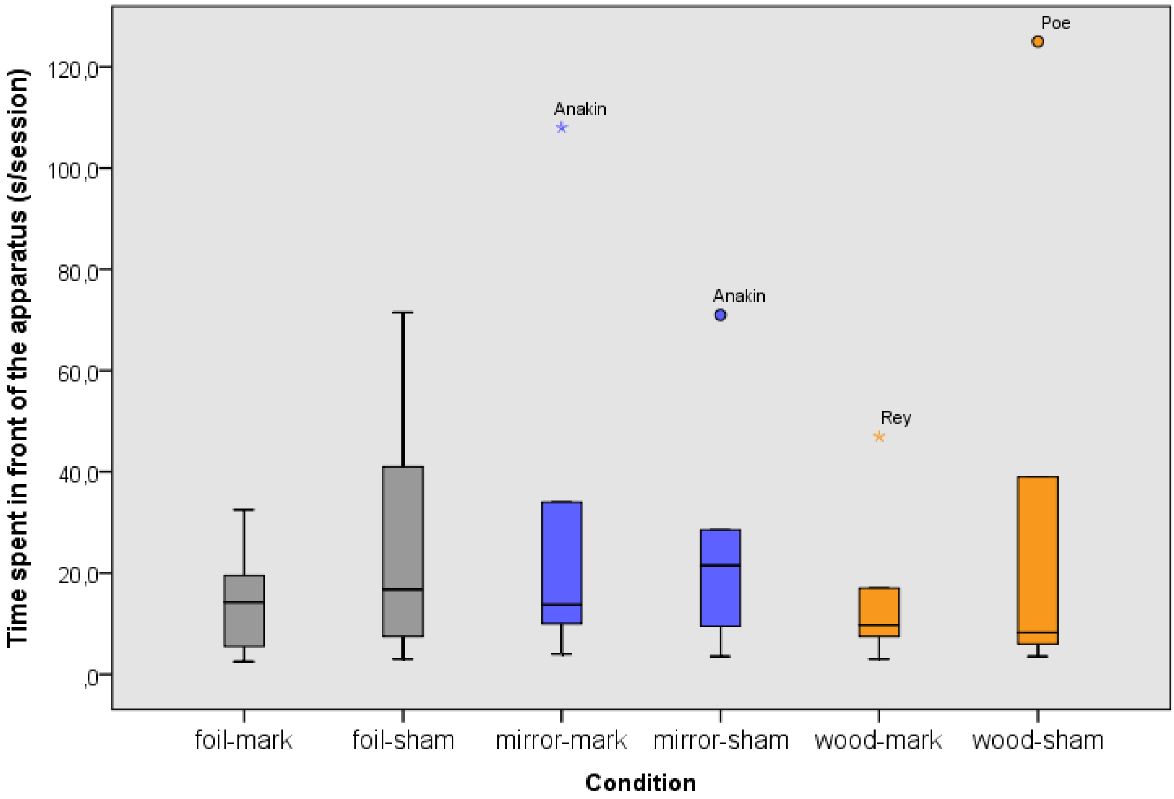

Figure 6. Time spent in front of the apparatus in the different conditions (sec/session)
There was no significant difference between conditions
(Friedman: N = 6; χ^2 = 4,808; df = 5; p = 0,440).

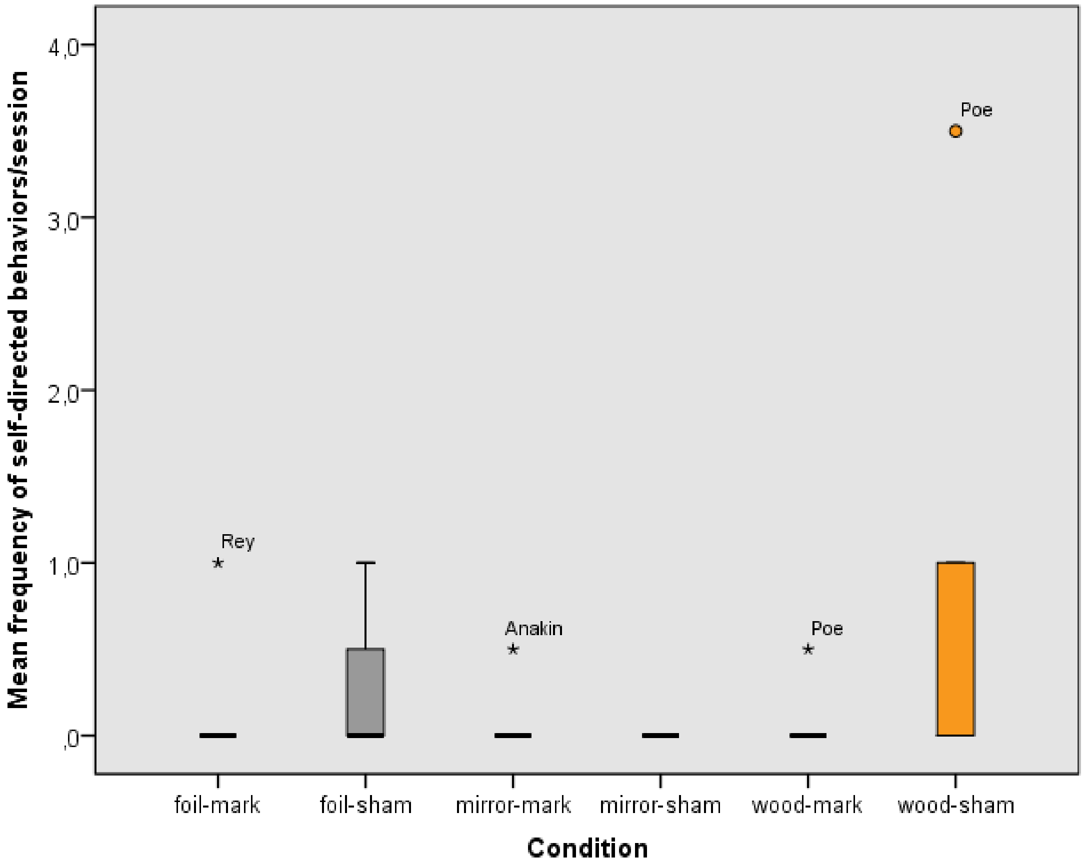

Figure 7. Frequency of self-directed behaviours in front of the apparatus in the different conditions
No significant differences could be found between conditions, only few instances of self-directed behaviours were shown
(Friedman: N = 6; χ^2 = 3,294; df = 5; p = 0,655)

<u>Post-mark behaviour</u>

Birds did not show any interest in the mark of conspecifics and did not try to remove it. There was only one occasion – after applying the mark on the first tested bird for the very first time – when one of the females shortly touched the mark on the male’s body.

<u>Visible Mark Control</u>

During these control sessions, it became clear, that there are individual differences in the motivation to remove marks with a certain colour from the body. Out of three different colours (red, yellow and green), Anakin removed only yellow from his body – however only before the Mark Test and did not react to it anymore during the second visible control conducted after the Mark Test. Poe and Rey did not react to yellow, only to red and green.

Other birds reacted to all tested colours, although with differences in the strength of the response (start of first preening-bout after receiving the mark and duration of auto-preening – Fig. 8a and 8b). In general, the two males (Anakin and Kylo) were the ones showing a stronger reaction to yellow compared to red. All the other birds – except for Anakin – reacted to the visible mark in a similar way before and after the Mark Test.

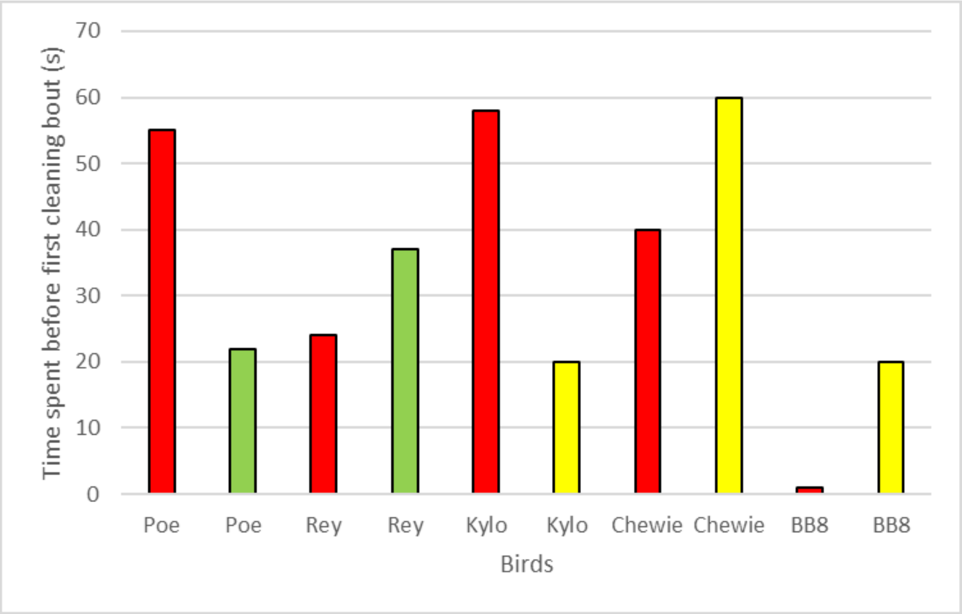

Figure 8a. Time spent before cleaning after receiving a visible mark before the Mark test

The colour of the bars represents the colour of the mark.

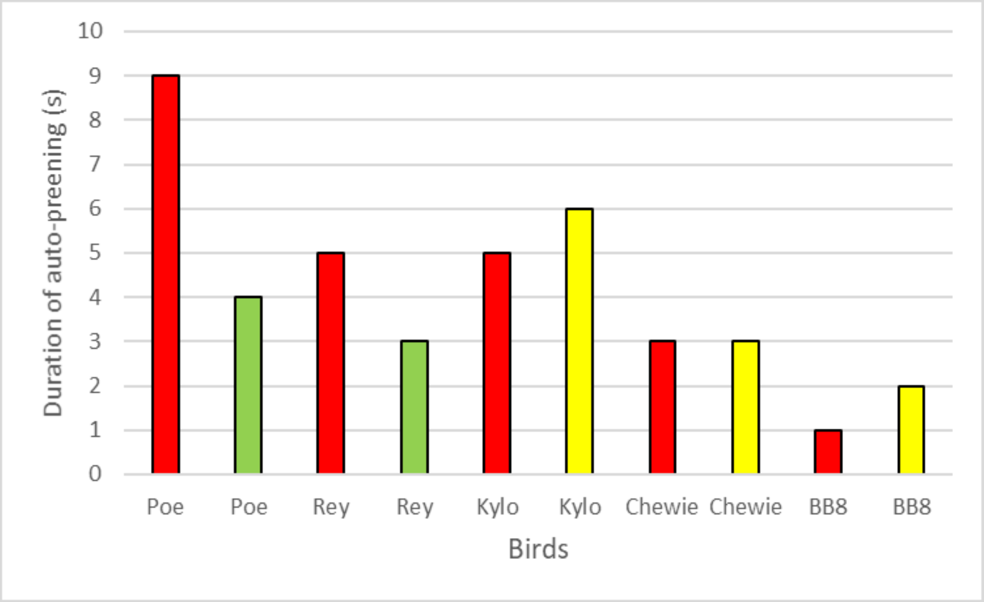

Figure 8b. Duration of auto-preening after receiving a visible mark before the Mark test

The colour of the bars represents the colour of the mark.

Pairwise exposure – Inside group

During the pairwise exposure birds only visited the apparatus to take the bait and in most cases they left immediately after. Only Leia landed in front of the apparatus almost in every session, the others did not even approach the apparatus for many sessions. There was no notable habituation to the different plates even after prolonged exposure. Startle behaviour was significantly different between conditions (Friedman: N = 4; χ^2 = 8,000; df = 2; p = 0,018), however post-hoc pairwise comparisons did not prove to be significant (Wilcoxon – mirror-foil: Z = -1,826; adj. p = 0,136; wood-mirror: Z = -1,826; adj. p = 0,136; foil-wood: Z = 0; p = 1). Time spent in front of the apparatus was different depending on the condition (Friedman: N = 4; χ^2 = 6,500; df = 2; p = 0,039), but no significant differences could be found using post-hoc comparisons (Wilcoxon – mirror-foil: Z = -1,826; adj. p = 0,204; wood-mirror: Z = -1,461; adj. p = 0,432; foil-wood: Z = -1,841; adj. p = 0,198). Birds did not show a difference in the frequency of visits in front of the plate between the different conditions (Friedman: N = 4; χ^2 = 5,143; df = 2; p = 0,076). Social behaviour towards the mirror image did not occur throughout the whole experiment. The frequency (Friedman: N = 4; χ^2 = 5,733; df = 2; p = 0,057) and duration of explorative behaviours (Friedman: N = 4; χ^2 = 3,500; df = 2; p = 0,174) were not significantly different. Birds spent a different amount of time inspecting the plate depending on the condition (Friedman: N = 4; χ^2 = 6,5; df = 2; p = 0,039;) but these differences were not significant after conducting post-hoc comparisons (Wilcoxon – mirror-foil: Z = -1,826; adj. p = 0,204; wood-mirror: Z = -1,461; adj. p = 0,432; foil-wood: Z = -1,841; adj. p = 0,198). Contingent behaviours were limited to mirror sessions but occurred only on two occasions. Birds never showed self-directed behaviour in front of the plate.

Group exposure – Inside group

This exposure type proved to be more successful compared to the pairwise exposure as birds tended to spend more time in front of the apparatus (Wilcoxon: N = 4; Z = -1,826; p = 0,068) and show less startle behaviour (Wilcoxon: N = 4; Z = -1,826; p = 0,068), however the difference did not reach significance level. Contrary to the pairwise exposure, behaviours of the four expected categories were exhibited. However, individual differences in the reaction to the apparatus were present: two of the birds monopolized the apparatus in the mirror condition – one of which spent more time in front of the apparatus than all the other birds in all three conditions. Startle behaviour occurred with a differing frequency depending on the condition (Friedman: N = 4; χ^2 = 7,538; df = 2; p = 0,023) but only on a few occasions. Post-hoc pairwise comparisons could not find significant differences between conditions (Wilcoxon – mirror-foil: Z = -1,841; adj. p = 0,198; wood-mirror: Z = -1,841; adj. p = 0,198; foil-wood: Z = -1,0; adj. p = 0,951). Frequency of visits to the front of the apparatus (Friedman: N = 4; χ^2 = 0,500; df = 2; p = 0,779) and time spent in front of the plate did not differ significantly between conditions (Fig. 9.). Social behaviours towards the mirror were only exhibited by the two birds monopolizing the mirror and one other bird vocalizing in front of the plate in the control conditions. No significant differences could be found between the three conditions for this category (Friedman: N = 4; χ^2= 0,8; df = 2; p = 0,670). The frequency (Friedman: N = 4; χ^2 = 0,500; df = 2; p = 0,779) and duration of explorative behaviours did not differ significantly, however looking down was significantly different between conditions (Friedman: N = 4; χ^2= 7,538; df = 2; p = 0,023). Post-hoc comparisons did not show significant differences (Wilcoxon – mirror-foil: Z = -1,826; adj. p = 0,204; wood-mirror: Z = -1,826; adj. p = 0,204; foil-wood: Z = -1,0; adj. p = 0,951). Contingent behaviours were shown almost exclusively in the mirror condition - with one stretching occurring once in front of the wooden plate - however the difference did not reach significance level (Friedman: N = 4; χ^2 = 5,600; df = 2; p = 0,061). Self-directed behaviours in front of the plate were not significantly different between conditions (Friedman: N = 4; χ^2 = 2,6; df = 2; p = 0,273).

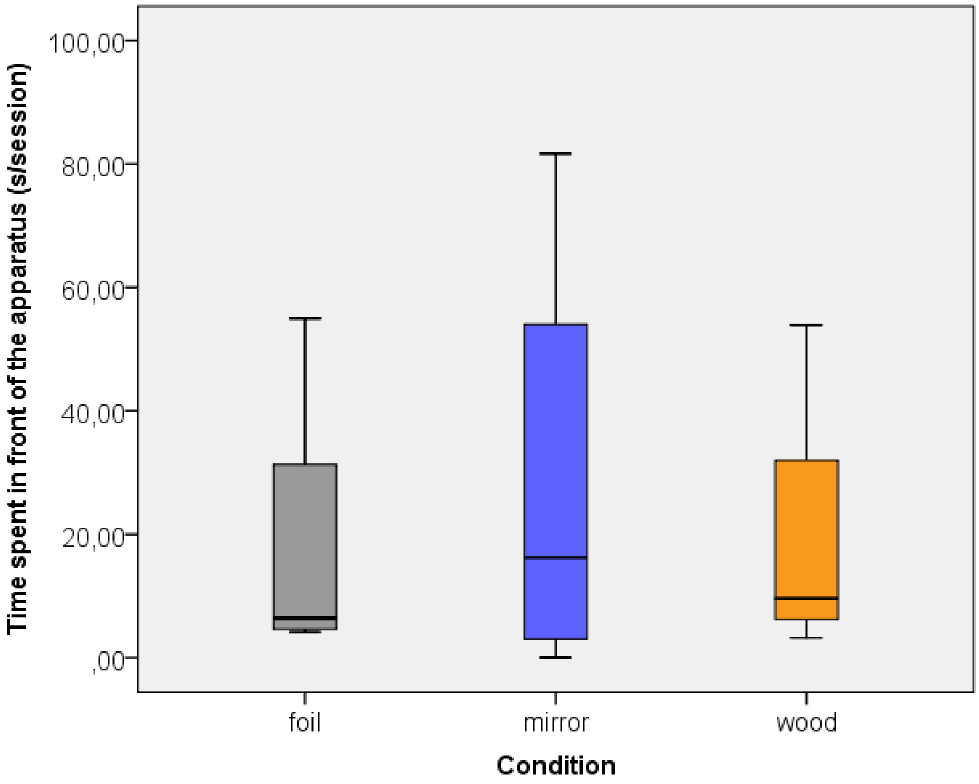

Figure 9. Time spent in front of the apparatus in the different conditions (sec/session)
There was no significant difference between conditions

Birds of the inside group also showed behaviours of all four categories, however the pattern of these does not resemble to that seen in the literature on the group level. Looking at the frequency of these behaviours, we can conclude, that even though social behaviours were starting to be less frequent during the last few mirror sessions, contingent behaviours were also diminishing after prolonged exposure to the mirror. Explorative behaviours showed the highest frequency and self-directed behaviours the lowest (Fig. 10.)

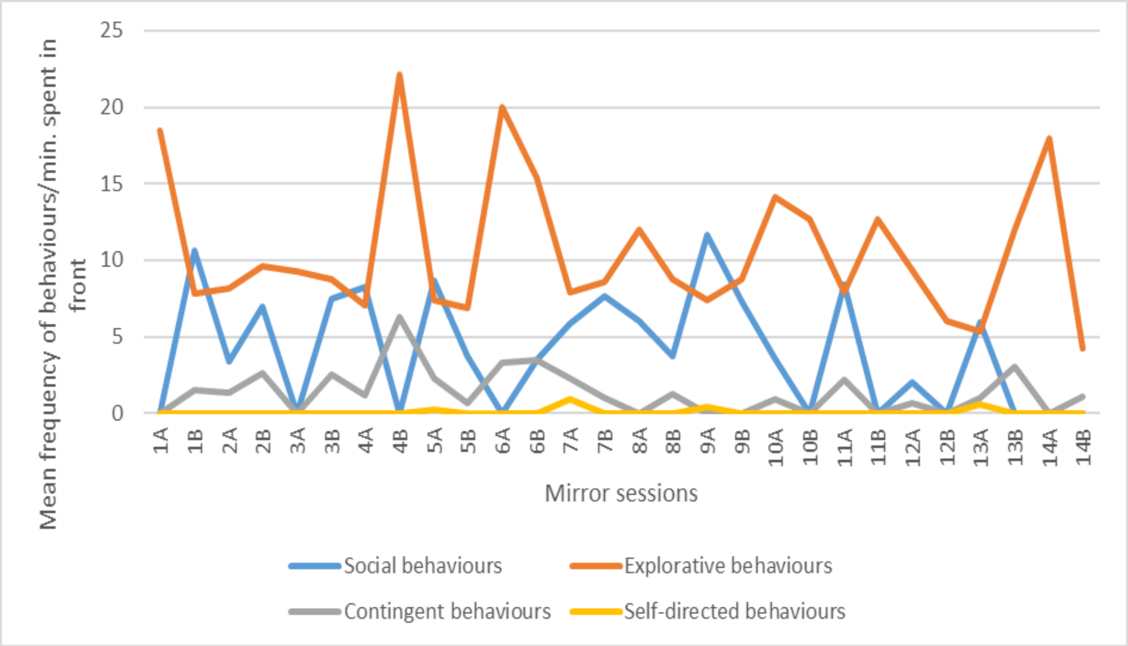

Figure 10. Frequency of behaviours in each category/minutes spent in front of the mirror
A-sessions stand for sessions recorded in the morning, B-sessions were recorded in the afternoon of the same day.

Furthermore, there was a significant difference both between and within days of exposure. The first and second days of exposure in the mirror and the wood conditions were significantly different (Fig. 11.; Wilcoxon: mirror: Z = -2,571; p = 0,01; wood: Z = -1,986; p = 0,047), suggesting habituation in case of the mirror, where birds spent less time in front of the mirror during the second exposure day compared to the first one. On the contrary, birds tended to spend more time in front of the wooden plate on the second days of exposure. In case of the foil, no significant difference was found (Wilcoxon: Z = -1,096; p = 0,273). When comparing the first and second session of each day, a significant difference was found in the mirror condition (Wilcoxon: Z = -2,314; p = 0,009), namely, birds spent more time in front of the mirror during the first sessions of each day, suggesting habituation. In case of the control conditions, no difference could be found (Wilcoxon - wood: Z = -1,812; p = 0,07; foil: Z = -0,944; p = 0,345).

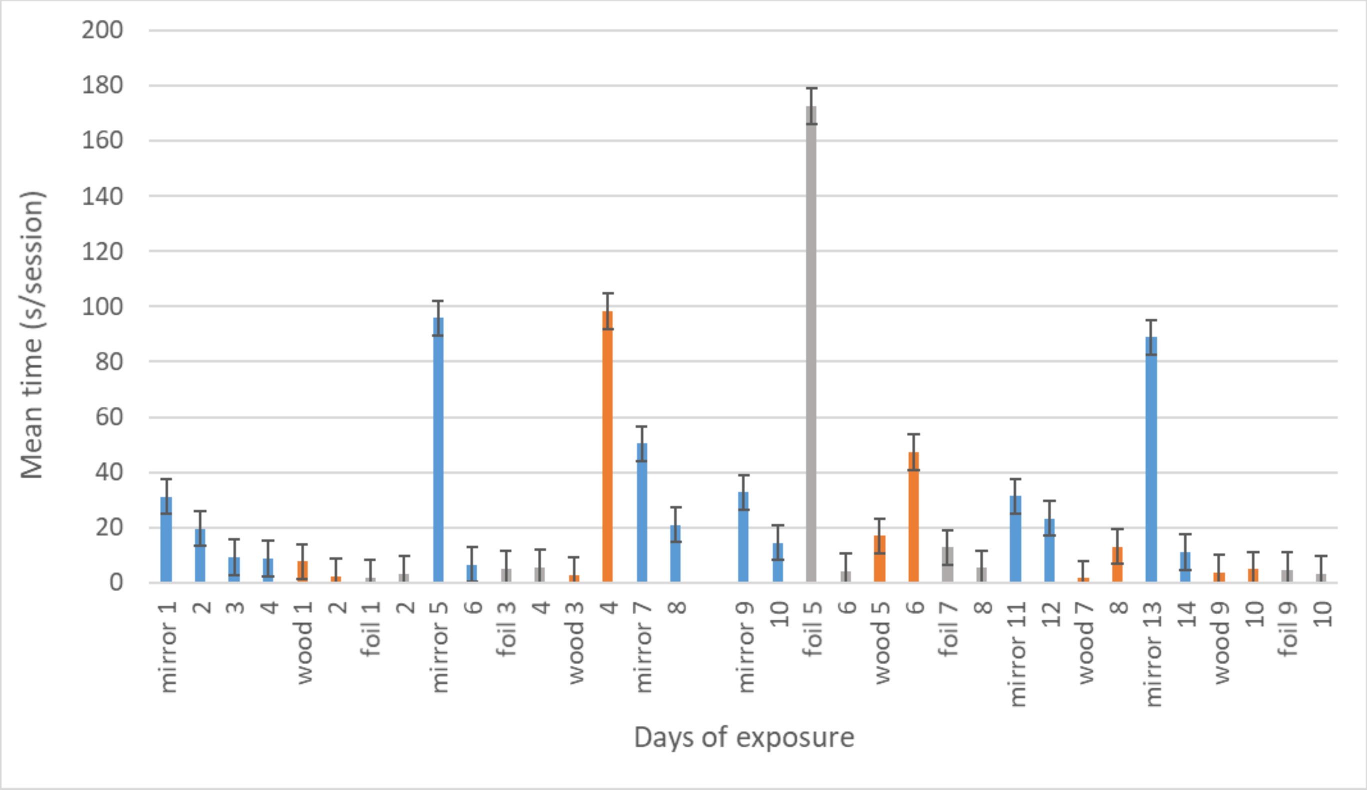

Figure 11. Mean time spent in front of the apparatus
Mean frequencies are shown for each day of exposure in chronological order of sessions. Time spent in front of the mirror and in front of the wood was significantly different on the first and second day of exposure (Wilcoxon: mirror: Z = -2,571; p = 0,01; wood: Z = -1,986; p = 0,047).

There were differences between the exposure types considering the time spent in front of the plate (Fig. 12.) and the frequency of startle behaviours (Fig. 13.), which allows us to assess, which one of them represented the most successful and the least stressful way to test this species. Group exposures proved to be successful in case of both groups, however the differences in the time spent in front of the plate and in the frequency of startle behaviour did not reach significance level. The inside group tended to spend more time in front of the plate (Wilcoxon: N = 4; Z = -1,826; p = 0,068) and show less startle behaviour (Wilcoxon: N = 4; Z = -1,826; p = 0,068) during the group exposure compared to the pairwise exposure. In case of the outside group, no such trend could be found for either the time spent in front (Wilcoxon: N = 6; Z = -0,314; p = 0,753) or the frequency of startle behaviours (N = 6; Z = -0,736; p = 0,462). In case of the control sessions, half of the outside group did not visit the foil during the group exposure but performed better during the individual sessions, once they habituated to the different conditions. Pairwise and individual exposures were characterized by the highest frequency of startle behaviours.

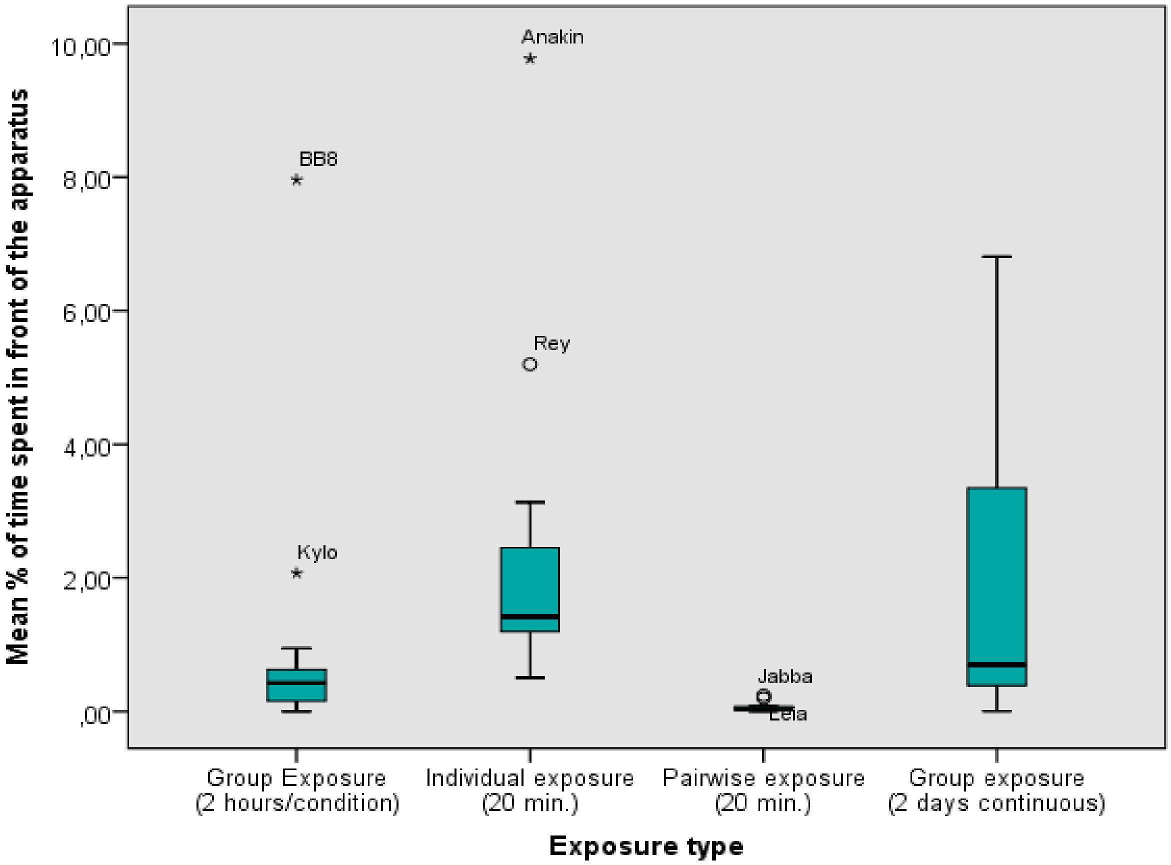

Figure 12. Mean % of time spent in front of the apparatus during the different exposure types

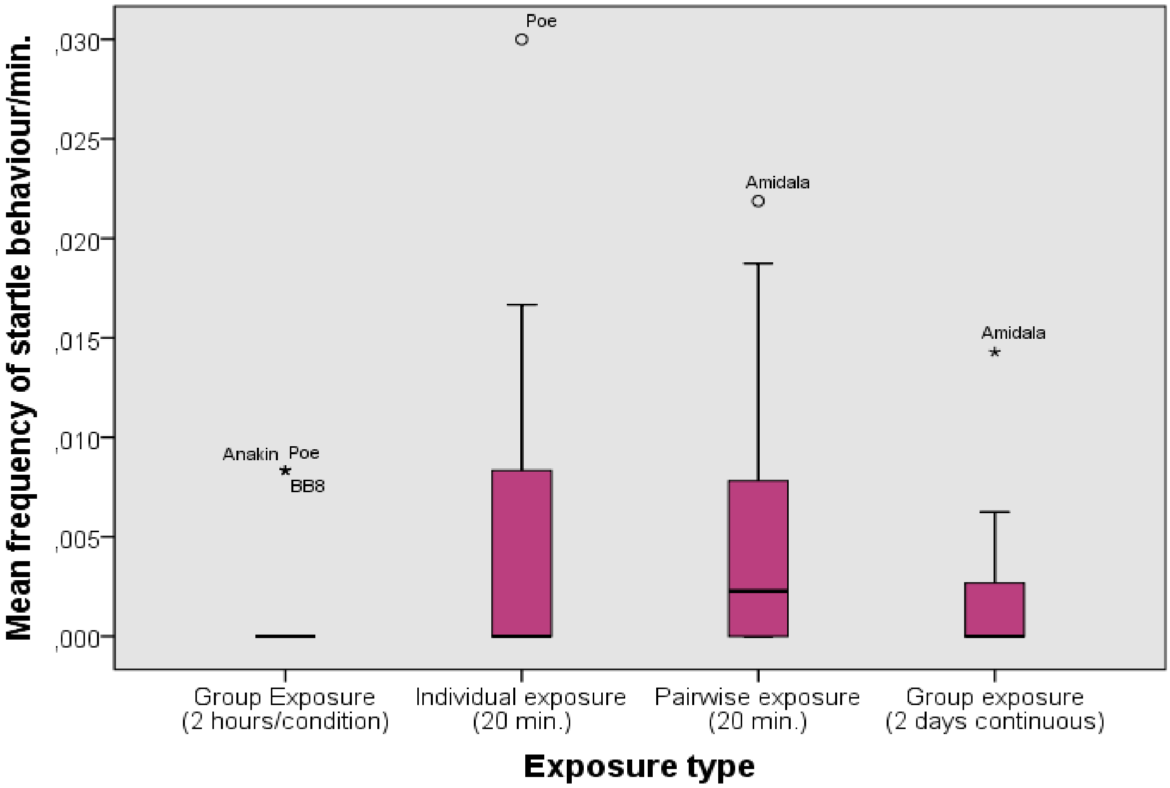

Figure 13. Mean frequency of startle behaviours/minute during the different exposure types

Discussion

In this study, azure-winged magpies did not show any kind of behaviour indicating mirror self-recognition. Furthermore, birds did not show a significant preference for the mirror over the controls. Behaviours from each of the four categories were shown in front of the mirror at some point of the exposure and are comparable to that of other species. However, birds did not seem to go through the different stages of behaviours as described for chimpanzees (Gallup, 1970) and most other tested animals. The differences in the time spent in front of the apparatus and in the frequency of startle behaviours depending on the type of exposure indicates, that group facilitation might reduce neophobia and help the animals get used to the experimental setting.

Birds showed individual differences in their responses towards both the mirror and the controls, namely that some of the birds showed a preference for the mirror over the controls and engaged in contingency checking and explorative behaviours directed towards the mirror, while other subjects did not show such preference for the mirror. This is at least partially consistent with the literature – where even in chimpanzees, only 75 % of individuals can pass the Mark Test (Povinelli et al., 1993), in case of Eurasian magpies, only two out of five birds showed evidence of mirror self-recognition (Prior et al., 2008) and Clark's nutcrackers also showed individual differences when reacting to the mark (Clary & Kelly, 2016). Therefore, it is not surprising to find individual differences in the reaction towards the mirror in the azure-winged magpies, even if none of our subjects showed any behaviours indicative of mirror self-recognition.

Contrary to the literature (e.g. Prior et al., 2008; Soler et al., 2014), subjects did not show a clear preference for the mirror on the group level, although a few individuals did spend more time in front of the mirror compared to the controls, whereas others barely approached it. There were also noticeable differences between the exposure types: Kylo and BB8 monopolized the mirror during the group sessions exhibiting social displays and displacing each other in front of the mirror. During this exposure they were the only ones showing a clear preference for the mirror and others did not have the chance to spend time in front of the mirror. However, this preference was not shown during the individual sessions, where they barely approached the mirror. Therefore, it is possible that these two birds were actively avoiding the mirror after they encountered the "conspecific" during the group exposure. Furthermore, two birds from the inside group - Jabba and Amidala - barely approached the mirror, as members of the inside group are generally warier and show stronger neophobic reactions compared to the outside group. Some of the birds from both groups occasionally spent the whole length of a session resting in front of the plate, which seemed to be spontaneous and happened in all three conditions.

When taking a closer look at the occurrence of the four behavioural categories on an individual basis, we can conclude, that social behaviours were shown only by some birds and at a rather low rate and behaviours of this category were starting to diminish around the end of the exposure, consistent with the findings in species which pass the Mark test (e.g. Prior et al., 2008; Gallup, 1970). However, our subjects showed behaviours from all four categories throughout the experiment and after prolonged exposure to the mirror, all these behaviours were starting to be reduced.

Birds were observed on some occasions to use the apparatus as a hiding spot for their cache both during and outside of experimental sessions. The caches were located inside of the apparatus, where the interchangeable plates belong. Some of the birds were clearly trying to access hidden food during experiments, however it was not possible because of the plate. According to these observations it is possible that in some cases birds' interest was not directed towards the plate in particular, but rather towards the previously hidden food, which does not depend on the reflecting quality of the plate in the apparatus. Thus, looking for hidden caches might be the reason why they did not show a preference for the mirror and showed explorative behaviours also in case of the controls.

Most of the social behaviours – excluding vocalizations - were shown by two females in the mirror condition. Although some males also ruffled their feathers in front of the mirror occasionally, frequent social displays were only shown by the dominant females (BB8 and Leia) in both groups (based on behavioural observations). The breeding pair of the inside group (Han and Leia) showed a repeating pattern considering the visits to the mirror during the group exposures: when Leia landed in front of the apparatus, Han followed her immediately almost on every occasion. While Leia was continuously performing aggressive displays, Han explored the apparatus shortly (and begged for food to Leia on some occasions) and left soon after. As every member of the colony is thought to participate in territory defence in this species (Bayandonoi, 2016), it could be that the male was attracted by the female's aggressive behaviour Furthermore, it could suggest that even if the birds did not show any signs of self-recognition, males did not treat their mirror-image as a potential threat. Allo-feeding and displacement between Han and Leia were also common, however only in front of the mirror and not in the control sessions. This could be because Leia got excited only in case of the mirror and as soon as Han went there to check what is the reason for her behaviour, he saw that she has food and started begging to her. Vocalizations in front of the apparatus mainly consisted of soft calls and begging calls, the first of which were not directed to any conspecific in particular and the latter being directed towards conspecifics, but not the mirror-image. However, neither one of the call types was different in the three conditions.

Visible mark tests revealed individual differences in the strength of the response towards the mark depending on its colour. As the red mark is in strong contrast with the light breast feathers of these birds, it is not surprising, that most of the birds showed a stronger reaction to red, which is easier to see on their feathers compared to yellow or green. Since Anakin was the only one not showing any reaction to the red mark, it could be that he has some kind of deficiency with his colour vision. Kylo also showed a stronger reaction to yellow compared to red, however since the time spent until the first cleaning and the duration of auto-preening in case of the red and the yellow mark differed only by 40 seconds at most (Fig.8a and 8b), it could well be, that on the day of marking with red, he was distracted by something and this caused the differences.

Contrary to our expectations, birds did not preen their marked conspecific during the post-mark observations, which could suggest that allo-preening is not elicited by visual stimuli on the body of conspecifics, but it is rather an act to strengthen pair bond as shown in many other corvid species (Kilham, 1990).

The differences found between the exposure types let us conclude that group exposures might be the best way to compare the performance of two groups showing differences in their ability to habituate to new situations. Namely, the inside group consists of birds which were raised by their parents and came from a zoo, whereas almost all the members of the outside group were hand-raised and all of them are used to human proximity. Therefore, in case of the inside group where birds are shy and show strong neophobic reactions, group exposure might be a suitable way to help them habituate to the experimental setting and reduce neophobia through group facilitation. In this study, the inside group showed difficulties getting used to the setup during the pairwise exposure and during the group exposure, they successfully habituated to the apparatus to the same extent as the outside group. Other studies on Corvids (Prior et al., 2008; Soler et al., 2014; Kusayama et al., 2000; Medina et al., 2011; Clary & Kelly, 2016) tested the birds individually, which would leave more time to explore the mirror without being disturbed by conspecifics, however this method was successful only in case of the magpies (Prior et al., 2008) and all the other studies failed to replicate those results, Therefore our results cannot be explained entirely by the fact, that not all the birds got individual exposure and they were all tested in their home aviaries.

When designing the methods, our priority was to test the birds in the least stressful way possible, which is why they were tested in their home cages – contrary to most of the previous studies, where subjects were placed in tiny experimental cages and were forced to face the mirror as they had no chance to avoid it or to retreat. The only disadvantage of our setup was that distractions – coming from either the rest of the group or from outside (e.g. crows calling in the distance) – could have likely influenced the results. On the other hand, since each bird visited the apparatus multiple times in each condition, we can conclude that potentially they could have shown mirror self-recognition despite all the distractions. The lacking evidence for mirror self-recognition in this species is surprising, considering that azure-winged magpies share the characteristics of species passing the Mark Test. This could indicate that the ability for mirror self-recognition is not present in every member of the Corvid family but there are interspecific differences in the reaction to mirrors. Jungle crows (Kusayama et al., 2000) and New-Caledonian crows (Medina et al., 2011) showed only social responses towards their reflection, which did not diminish after prolonged exposure to the mirror, although New-Caledonian crows were able to locate food using the mirror (Medina et al., 2011) On the other hand, jackdaws (Soler et al., 2014), carrion crows and common ravens (Vanhooland et al., in press) showed not only a preference for the mirror over the controls but also the common string of behaviours were exhibited in front of the mirror. Eurasian magpies were even shown to be able to pass the Mark test (Prior et al., 2008). Therefore, azure-winged magpies could represent part of a 'continuum' for the ability of mirror self-recognition found in Corvids, on one end with species which treat their image as a conspecific (i.e. jungle crows and New-Caledonian crows) and on the other end species with the ability for self-recognition (i.e. Eurasian magpies).It is also possible, that birds were overwhelmed by the properties of the mirror, as in the wild, they are used to blurred reflections of themselves (i.e. on water surfaces). This hypothesis is supported by the study conducted on Clark's nutcrackers (Clary & Kelly, 2016), where birds showed enhanced mark-directed behaviour in front of a blurred mirror compared to a regular mirror. Authors argue, that learning about contingent motion in front of the mirror is an important step towards mirror self-recognition, however in case of a regular mirror, birds might be distracted by a high amount of identity information provided by the mirror. This finding could at least partially explain the results of this study. Even though almost all our subjects showed at least one instance of contingent behaviour, these behaviours were not exhibited consistently, which might indicate that birds did not learn enough about the properties of the mirror. The only exception in this case is Anakin, who showed contingent behaviour consistently starting at the beginning of the experiments, however he failed to react to the visible mark after the Mark test, which renders lacking evidence for self-directed behaviour in the mirror-mark condition inconclusive in his case.

Since almost all the birds – except for Anakin – reacted to the mark when it was directly visible on their body, we can rule out the possibility that birds were not motivated to remove a colourful mark from their body. Using glycerine mixed with food colouring seems to be a good material to mark this species and could be useful for testing other bird species as well, contrary to marking with stickers, as it has been reported by Soler et al. (2014). Furthermore, we can conclude that in some species, it might be possible to mark animals using training and gradually getting them used to the procedure instead of marking them by force.

Furthermore, our findings indicate that complex cognitive abilities, high relative brain size and tendency for empathetic behaviour might not be the only prerequisites for mirror self-recognition and also other species lacking these abilities might be able to pass the Mark test as it has been shown in a fish species, the cleaner wrasse (Kohda et al., 2019).

Further research on this species investigating mirror self-recognition is needed using a similar setup to that of the nutcracker-study (Clary & Kelly, 2016), where food-storing – an ecologically important behaviour - was used to evaluate birds' perception of their mirror image. Investigating animals' ability to locate hidden food using a mirror could be also interesting in this species as it was performed with New-Caledonian crows (Medina et al., 2011). Another possibility would be to test, if birds show a preference for the mirror over a conspecific behind a glass as it has been shown in some bird species (Gallup and Capper, 1970; Ryan, 1978).

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