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Mirror, Mirror on the Wall: Preventing Shadow Boxing through Habituation A Pilot Study

Sharline Cully[1], Nancy Rebout[2], Lucy V. Kemp[3,4], & Samara Danel[3,5]

[1]University of Liege

[2]UniLaSalle, Université d'Artois

[3]Mabula Ground Hornbill Project

[4]Department of Environmental Sciences, University of South Africa

[5]BirdLife South Africa

Shadow boxing is the aggressive response of an animal to its reflection. When the species is strong enough to break surfaces (e.g., bear, monkey, woodpecker), this behaviour can lead to human-wildlife conflicts. In this pilot study, we assessed whether shadow boxing is subject to habituation (learning to ignore stimuli) in Southern ground-hornbills (*Bucorvus leadbeateri*). In the *Mirror task*, birds were repeatedly exposed to unbreakable mirrors (habituation). Subsequently, one mirror was presented at a different location (test). In the *Neophobia task,* a food reward was placed next to novel objects. Ground-hornbills did not habituate to the mirrors, but they differed in their levels of neophobia.

Keywords: ground-hornbill, habituation, human-wildlife conflict, learning-conservation interface, learning, neophobia, shadow boxing

鏡よ鏡、壁に映るもの：馴化によるシャドーボクシングの防止に関する予備的研究

シャドーボクシングは自身の鏡像（反射）に対する動物の攻撃的な反応である。その種が表面を破壊するほどの力を持っている場合（例：クマ、サル、キツツキなど）、その行動は人間と野生動物の衝突につながる可能性がある。この予備的研究では、ミナミジサイチョウ *Bucorvus leadbeateri* を対象として、シャドーボクシングが馴化（刺激を無視することを学習）の対象となるかを評価した。鏡を用いた課題において、鳥は割れない鏡に繰り返しさらされた（馴化）。続いて、別の場所に鏡が 1 枚提示された（テスト）。新奇恐怖課題では、食物報酬は新しい物体の隣に配置された。ミナミジサイチョウは鏡に馴化しなかったが、新奇恐怖の度合いには個体差が見られた。

キーワード：ミナミジサイチョウ、馴化、人間と野生動物の衝突、学習―保全インターフェース、学習、新奇恐怖、シャドーボクシング

Espejito, espejito en la pared: Prevención del boxeo de sombra mediante la habituación
Un estudio piloto

El boxeo de sombra es una respuesta agresiva de un animal dirigida hacia su propio reflejo. En especies con la fuerza suficiente para romper superficies (e. g., osos, primates o pájaros carpinteros), este comportamiento puede generar conflictos entre humanos y fauna silvestre. En el presente estudio piloto, se evaluó si el boxeo de sombra está sujeto a la habituación (aprender a ignorar estímulos) en cálao terrestre sureño (*Bucorvus leadbeateri*). En la *tarea del espejo*, las aves fueron expuestas repetidamente a espejos irrompibles (habituación). Posteriormente, se les presentó un espejo en un lugar diferente (prueba). Para la *tarea de neofobia*, se administró una recompensa de comida junto a objetos nuevos. Los cálaos terrestres no se habituaron a los espejos, pero difirieron en sus niveles de neofobia.

Palabras clave: cálao terrestre, habituación, conflicto entre humanos y fauna silvestre, interfaz aprendizaje-conservación, aprendizaje, neofobia, boxeo de sombra

Please send correspondence to Samara Danel, BirdLife South Africa, Johannesburg, South Africa. E-mail: samara.danel@gmail.com

Habituation—'learning to ignore'—is the decrease in response strength to a recurrent stimulus (Rankin et al., 2009; Thompson, 2009; Thorpe, 1963). Traditionally viewed as a non-associative process, comparative studies have found evidence for the role of *context* in habituation (reviewed in Dissegna et al., 2021). Animals sometimes learn to ignore a stimulus by associating it with the surrounding environment. Chicks (*Gallus gallus*), for instance, exhibit a progressive decline of freezing behaviour to acoustic stimuli (Chiandetti & Turatto, 2017). This behaviour recovers when chicks are placed in a new environment. Beyond the stimulus features (e.g., intensity, frequency), the context of stimulation may thus matter. So far, experiments testing this prediction have been rare and subject to mixed patterns of findings. To develop a broader understanding of context-specific habituation, more species and taxa need to be evaluated.

Importantly, use of habituation can benefit wildlife conservation (e.g., by learning *not* to respond to human disturbance through repeated exposure; Bejder et al., 2009). Whether this learning process may be exploited to reduce shadow boxing—when animals attack their own reflection in shiny surfaces (a window, a windscreen, or other reflective infrastructures)—remains to be investigated. This behaviour can lead to much damage, especially when the species is strong and large, resulting in human-wildlife conflict.

Southern ground-hornbills (*Bucorvus leadbeateri*) are sedentary and highly territorial birds, which are solely found in Africa (Kemp & Kemp, 1980). In anthropogenic environments, they use their powerful bill to attack their reflection as if it were an intruder (Theron et al., 2013; e.g., in a morning, a single group can break over 400 windows; LK personal observation). As a result, humans locally persecute this species, which is endangered in South Africa (Kemp & Rose, 2025). Although some conservation tools have been developed for Southern ground-hornbills (e.g., acoustic bird deterrents, perforated vinyl to reduce reflection; Kemp et al. 2023), shadow boxing is still recognised as one of the primary reasons for the species' decline. Because access to additional subjects is severely constrained by this bird's endangered status, small-scale pilot experiments represent an essential first step for hypothesis generation and methodological optimisation.

In an attempt to address this human-wildlife conflict, we aimed to assess whether (a) a prolonged exposition to unbreakable mirrors leads to habituation—a decrease of behaviours (i.e., territorial defence: facing, touching, and pecking at mirrors, see Video 1 in Supplementary Material), (b) habituation is context-specific—natural behaviours are *de novo* exhibited when the familiar stimulus (i.e., the mirror) is presented at a different location, and (c) habituation relates to neophobia (fear of novelty). We predicted that behaviours directed at the mirrors should decrease over trials during the habituation phase (Prediction 1), but restart in a new environment during the test phase (Prediction 2). We also predicted that neophobia should delay confrontation to the mirrors, and thus time at which neophobic individuals show *true* habituation (i.e., not responding to mirrors; Prediction 3).

Method

Study Site and Subjects

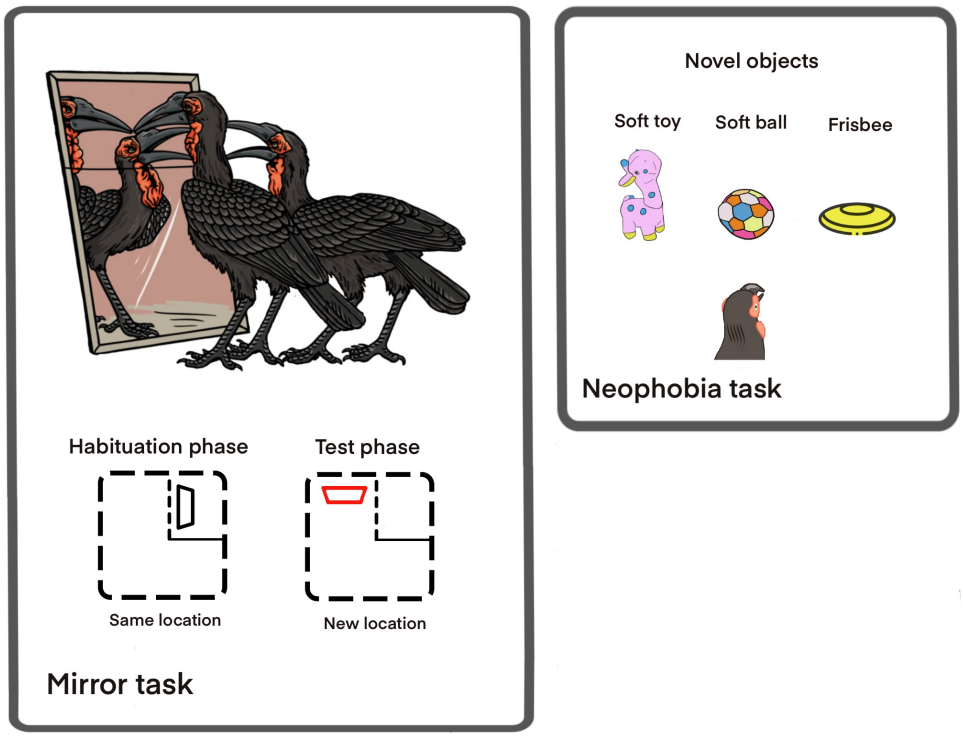
Initially, during September-November 2019, three groups of captive Southern ground-hornbills (*Bucorvus leadbeateri*) participated in this study. However, for security purposes, the experiment could be maintained only with Group 2 (see Security Statement in Supplementary Material). Some birds showed aggressive behaviours towards the experimenter, resulting in the cessation of the experiment. In Group 2, four females (Kalula, Mud, Nkosi, and Red Rocks) lived in an outdoor aviary at the Baobab Southern Ground-hornbill Conservation Rearing Centre (Loskop Dam Nature Reserve, Mpumalanga, South Africa), a collaboration between the Mabula Ground Hornbill Project and Mpumalanga Tourism and Parks Agency. The aviary included two compartments (primary compartment of 30 m^2: test phase of *Mirror task*, secondary compartment of 4 m^2: habituation phase of *Mirror task* and *Neophobia task*). Three subjects were a minimum age of five years, the fourth one was a juvenile (i.e., Kalula, which was two-and-a-half-year-old). All four individuals had previously participated in behavioural experiments between June-November 2019. More specifically, these experiments included the study of social learning, exclusion performance, animal-human communication, or reversal learning (see STRANGE Statement in Supplementary Material).

Experimental Setup

In the *Mirror task,* we used two unbreakable (i.e., entirely made from stainless steel) mirrors (80 cm in length, 80 cm in width; Figure 1). A thin horizontal black string prevented both mirrors from falling on the birds. To assess fear of novelty, objects need (a) not to resemble natural preys (or predators), and (b) be artificial (coloured, human-made items; e.g., Danel et al., 2024a, 2024b). Thus, in the *Neophobia task,* we used three novel objects: a yellow Frisbee (15 cm in diameter, 20 cm in height), a pink giraffe soft toy (15 cm in length, 10 cm in width), and a multicolour soft ball (17 cm in diameter, 10 cm in width; Figure 1). The food reward (i.e., used in the *Neophobia task*) consisted of one-at-a-time defrosted pieces of mice or chicken heads/legs (based on previous experiments; e.g., Danel et al., 2022; Danel et al., 2023). Data were collected using a video camera (Samsung camera HMX-F90).

Figure 1

Overview of the Tasks Conducted with Southern Ground-hornbills



Note. In the Mirror task (left panel), unbreakable mirrors are presented repeatedly for assessing learning (habituation phase). After the habituation phase, mirrors are placed in a new location (test phase). In the Neophobia task (right panel), three novel objects are used as stimuli for evaluating neophobia (from left to right: yellow Frisbee, multicolour soft ball, and pink giraffe soft toy).

Procedure

Subjects were exposed to the mirrors (birds could enter or leave the test area at any time). In the *Neophobia task*, each bird was temporarily isolated from conspecifics.

Mirror Task

Habituation Phase. When all individuals were present in the primary compartment, the experimenter closed the door of the secondary compartment. Then, the experimenter placed the two mirrors next to each other in the secondary compartment. Subsequently, the experimenter triggered the camera and opened the door of the secondary compartment. Ground-hornbills were then allowed to enter the secondary compartment to interact with the mirrors. Twenty trials in total were administered (1 trial per day on successive days, duration of each trial: 10 minutes).

Test Phase. Here, one mirror was present at another location in the primary compartment (see test phase in Figure 1). During transport, the mirror was covered by a piece of fabric. After placing the mirror, the experimenter slowly removed the fabric and triggered the camera (1 single trial, duration: 10 minutes).

Neophobia Task

Each test day, we presented a novel object (test condition) and no novel object (control condition) next to a food reward (Greenberg, 1983). Six trials in total were administered (three trials with one object, three trials with no object). The order of presentation of the novel objects (i.e., yellow Frisbee, pink giraffe soft toy, and multicolour soft ball) and condition (test vs. control) varied randomly across birds (2 trials per day, 1 h apart, maximum duration of 1 trial was 8 minutes). In both tasks, each trial started when the experimenter triggered the camera and ended after the maximum trial duration had elapsed (i.e., *Mirror task*) or after the subjects received the food reward (i.e., *Neophobia task*). Timing of trials varied between 9 a.m. to 5 p.m.

Data Analysis

All tests were video recorded and continuous second-by-second coding of the videos was performed on Behavioral Observation Research Interactive Software (BORIS; Friard & Gamba, 2016), a free and easy-to-use software which allows providing accurate behavioral coding from video recordings or live observations (Friand & Gamba, 2016). A second observer re-coded a random of 20% video recordings (4 out of 20 trials in total of the habituation phase—*Mirror task*). Inter-observer reliability was high and significant ($p < .001$; intraclass correlation coefficient (ICC) = .999).

Mirror Task

We coded the time elapsed in seconds from when the birds *faced* the mirrors (i.e., the bird's beak is directed perpendicularly at the mirrors) to when they stopped facing (i.e., turned their beak). We also coded the number of times ground-hornbills (a) *touched* the mirrors (i.e., the bird softly contacts the mirrors with the beak) and (b) *pecked* at the mirrors (i.e., the bird's head noticeably moves backward and then hits the mirrors with the beak).

To study time elapsed, we implemented one generalized linear model (GLM) with a gamma distribution (Model 1) and two GLMs with a negative binomial distribution (Model 2 & Model 3; as Poisson models showed over dispersion). The response variable was facing duration (in sec) for Model 1, touching occurrences for Model 2, and pecking occurrences for Model 3. In the models, we included the number of trials (Trials) and subject identity (Subjects) as fixed effects.

Neophobia Task

We coded the time elapsed in seconds from the start of the trial to when the bird got the food in the presence (test condition) *versus* the absence (control condition) of the objects. All subjects took the food reward (no censored data were reported). We ran a generalized linear model (Model 4) with a gamma distribution. Fixed factors were *Condition* (test condition and control condition), *Order* (sequence of novel objects presented), *Subject identity*, and *Object* (yellow Frisbee, pink giraffe soft toy, and multicolour soft ball).

Statistical analyses were performed using R version 3.6 (R Core Team, 2019) and we used the packages *irr* for inter-observer reliability (Gamer, 2010), *car* (function Anova; Fox *et al.* 2012) for extracting deviance tables and assess the significance of the fixed effects*, MASS* for performing gamma and negative binomial GLMs (Ripley et al., 2013), and *emmeans* for conducting *post hoc* tests (Lenth, 2016).

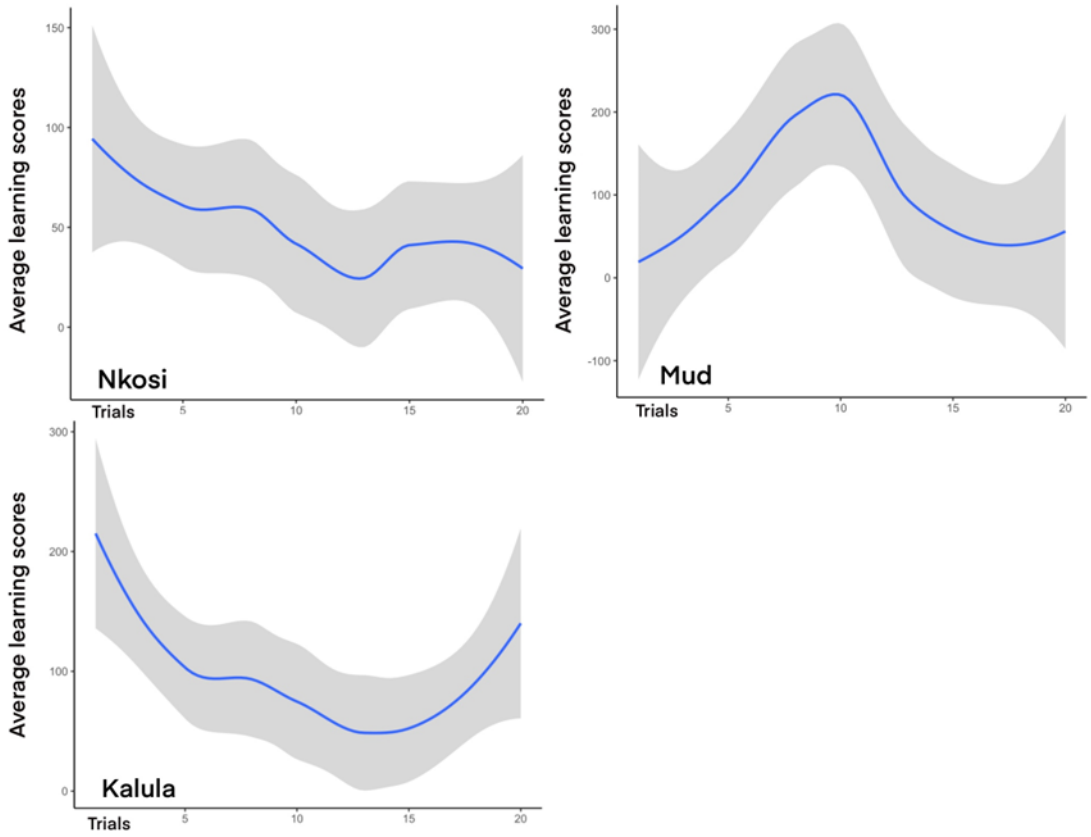
Results

Mirror Task

Mostly, ground-hornbills did not habituate to their reflection (Prediction 1). We also found behavioural variation between specific individuals. The mean duration ± SD of facing mirrors was 94 ± 65 sec for Kalula, 95 ± 105 sec for Mud, 50 ± 38 for Nkosi, and 49 ± 85 sec for Red Rocks. The mean number ± SD of touching mirrors was 6 ± 5 for Kalula, 3 ± 3 for Mud, and 2 ± 2 for Nkosi (the fourth individual, 'Red Rocks', never touched nor pecked the mirrors). The mean number ± SD of pecking mirrors was 13 ± 14 for Kalula, 5 ± 4 for Mud, and 2 ± 4 for Nkosi. For all models, number of trials (Trials) had no effect on each dependant variable (i.e., facing mirrors' duration – Model 1: *Trial:* $\chi^2 = -0.02$, $p = .25$; touching occurrences – Model 2: *Trial:* $\chi^2 = 1.69$, $p = .19$, and pecking occurrences – Model 3: *Trial:* $\chi^2 = 0.02$, $p = .87$). In other words, subjects did not habituate to their own reflection in the mirrors (Prediction 1; Figure 2). Touching and pecking occurrences differed across subjects (Model 2, Subject: $\chi^2 = 7.72$, $p = .02$; Model 3: Subject: $\chi^2 = 8.99$, $p = .01$). More specifically, Kalula touched (Model 2: 1.12 ± 0.428, z = 2.614, $p = .02$) and pecked (Model 3: 0.986 ± 0.343, z = 2.873, $p = .01$) more mirrors than Nkosi (Table S1 in Supplementary Material).

Figure 2

Subject Learning Curves of Facing Mirrors' Duration During the Habituation Phase of the Mirror Task



Note. Learning curve for one subject (Red Rocks) could not be implemented in the absence of sufficient data. For each graph, shaded areas indicate lower and upper bounds of the 95% CIs.

Neophobia Task

Generally, birds retrieved the food reward more quickly in the absence of novel objects. Latency to get the food reward also varied between some individuals. All subjects took the food reward regardless of the experimental condition (control *versus* test condition). *Condition* had a significant effect on the latency to get the food reward ($\chi^2 = 0.940$, $p < .01$): ground-hornbills took less time to get the reward when no object was present in the control condition compared to the test condition. *Subject* also had a significant effect on the latency to get the food reward: Mud (1.192 ± 0.406, $z = 2.940$, $p < .04$) took more time to get the food reward compared to Red Rocks (Table S2 in Supplementary Material).

Discussion

In this pilot study, we aimed to evaluate whether ground-hornbills habituate to their reflection in mirrors, the influence of context on this learning process, and if neophobia levels delay habituation. Contrary to our expectations, behaviours directed at the mirrors did not decrease over trials. Moreover, ground-hornbills varied in their levels of neophobia.

In the wild, a number of species (e.g., Dusky Sunbird, *Cinnyrus fuscus*; pin-tailed whydah, *Vidua macroura*; White-bellied Sunbird, *Cinnyris talatala*) perceive their self-images as threatening conspecifics over multiple years (Roerig, 2013). For welfare purposes, mirrors have been provided in captive social species (e.g., as sensory or social enrichments). However, mirror exposure can lead to adverse consequences (increase of submissive or aggressive behaviours; de Groot & Cheyne, 2016).

Due to limited sample size (n = 4 female subjects), these results require cautious interpretations. We cannot exclude the possibility that sampling variability led to the inclusion of subjects inherently less prone to habituation. Furthermore, to detect potential habituation effects, further studies should include a higher number of trials (> 20 trials) and a dishabituation control. Since this study was preliminary, we did not test whether a new stimulus provoked the reappearance of territorial defense. To ensure that a decrease of responses is due to habituation, we suggest using new mirrors or displacing original mirrors at another location within the test area.

In conclusion, mirrors have not become a neutral element during the habituation phase, for our tested females. Further experimental investigations are needed to draw firm conclusions including (a) a greater number of trials, (b) both sexes (for exploring potential sex roles), and (c) the development of *automated* mirrors that can be activated (i.e., opened) at a distance. These innovative devices may allow testing more individuals (e.g., highly aggressive alpha individuals; Koeppel et al., 2025), while providing safety for experimenters.

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Declarations

Ethics in publishing: data sets upon which published studies are based are available in Supplementary Material.

Animal welfare note: this experiment adheres to the ASAB/ABS guidelines for the treatment of animals in behavioural research and teaching and met the requirements of the Guide to Ethical Information Required for Animal Behaviour Papers. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. The experiment was approved by the SANBI NZG Research Ethics and Scientific Committee (RESC, permit number: SANBI NZG/RES/P19/14).

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Author Note

Sharline Cully no available ORCID identifier
Nancy Rebout https://doi.org/0000-0002-7071-0011
Lucy V. Kemp https://orcid.org/0000-0002-6765-9323
Samara Danel https://orcid.org/0000-0003-0233-2343

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