**Goats who stare at video screens – assessing behavioural responses of goats towards images of familiar and unfamiliar con- and heterospecifics**

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**Abstract**

Many cognitive paradigms rely on active decision-making, creating participation biases (e.g. subjects may lack motivation to participate in the training) and once-learned contingencies may bias the outcomes of subsequent similar tests. We here present a looking time approach to study goat perception and cognition, without the need to extensively train animals and no reliance on learned contingencies. In our looking time paradigm, we assessed the attention of 10 female dwarf goats (*Capra hircus*) towards 2D visual stimuli which were images of familiar and unfamiliar con- and heterospecifics (i.e. goats and humans) using an experimental apparatus containing two video screens. Spontaneous behavioural reactions to the presented stimuli, including the looking behaviour and the time spent with the ears in different positions were analysed using linear mixed-effects models. We found that goats looked longer at the video screen presenting a stimulus compared to the screen that remained white. Goats looked longer at images depicting other goats compared to humans, while their looking behaviour did not significantly differ when being confronted with familiar vs. unfamiliar individuals. We did not find statistical support for an association between the ear positions and the presented stimuli. Our findings indicate that goats are capable of discriminating between two-dimensional con- and heterospecific faces, but also raise questions on their ability to categorise other individuals regarding their familiarity using

35    2D face images alone. Our subjects might either lack this ability or might be unable to

36    spontaneously recognise the provided 2D images as representations of real-life

37    subjects. Alternatively, subjects might have shown an equal amount of motivation to

38    pay close attention to both familiar and unfamiliar faces masking potential effects. The

39    looking time paradigm developed in this study appears to be a promising approach to

40    investigate a variety of other research questions linked to how domestic ungulate

41    species perceive their physical and social environment.

42

43    **Keywords**

44    looking time; recognition; visual preference; ear position

## Introduction

Many cognitive paradigms rely on active decision-making, often combined with extended training periods in which subjects learn to respond to arbitrary stimuli. As a result, these paradigms can create participation biases (e.g. subjects may lack motivation to participate in the training) and once-learned contingencies may bias the outcomes of subsequent similar tests (Harlow, 1949; Rivas-Blanco et al., 2023). In particular, some species, such as prey animals, might show a hampered motivation to engage in decision-making tasks due to an increased alert behaviour in a test situation where individuals are typically isolated from the rest of the group for a short period of time. Active decision-making tasks may therefore be inappropriate in some specific contexts if the goal is to test for the population-wide distribution of cognitive traits in a species or to make adequate cross-species comparisons.

Looking time paradigms (experimental setups in which visual stimuli are presented to a subject and its corresponding visual attention to each stimulus is measured, see Wilson et al., 2023; Winters et al., 2015) were originally developed for research on the perception of preverbal human infants (Berlyne, 1958; Fantz, 1958) and have since been increasingly used in animal behaviour and cognition research, especially in non-human primates (e.g. Krupenye et al., 2016; Leinwand et al., 2022). One prominent experimental approach of the looking time paradigm, next to habituation- and violation-of-expectation-tasks, is the visual preference task (for a critical discussion of the term 'visual preference' see Winters et al., 2015). In this experimental setup, visual stimuli are presented either simultaneously or sequentially and a subject's preference for a particular stimulus is assessed by measuring its visual attention to each stimulus (Leinwand et al., 2022; Méary et al., 2014; Racca et al., 2010; Steckenfinger & Ghazanfar, 2009). One of the main assumptions of the visual preference task is that animals direct their visual attention for longer to objects or scenes that are perceived to be more salient to them, or that elicit more interest (Winters et al., 2015). An increased interest in specific stimuli can have multiple reasons, such as the perception of increased attractiveness or threat, novelty or familiarity (Wilson et al., 2023). However, the underlying motivation to show increased interest in a stimulus is often difficult to assess, as multiple motivational factors can simultaneously occur (for a critical discussion of the interpretation of the looking behaviour see Wilson et al., 2023). Visual preference tasks do not require intensive training of learned responses, are relatively fast to perform and provide a more

79  naturalistic setup compared to many decision-making tasks (Racca et al., 2010;
80  Wilson et al., 2023). Looking time paradigms might be particularly valuable for
81  assessing socio-cognitive capacities such as individual discrimination and recognition,
82  as social stimuli often have a higher biological relevance compared to artificial and/or
83  non-social stimuli and may therefore elicit a stronger behavioural response.

84      Individual recognition refers to a subset of recognition that occurs when one
85  organism identifies another according to its unique distinctive characteristics (Tibbetts
86  & Dale, 2007). This process may be important in an animal's social life as an animal
87  that recognises another individual, thus also recognises the sex and social status of a
88  familiar group member, an unfamiliar out-group conspecific or even the heterospecific
89  status of other animal species (Coulon et al., 2009). To achieve visual individual
90  recognition, many animal species rely on the process of face recognition (e.g. paper
91  wasps (*Polistes fuscatus*): Tibbetts, 2002; cichlid fish (*Neolamprologus pulcher*):
92  Kohda et al., 2015; cattle (*Bos taurus*): Coulon et al., 2009; sheep (*Ovies aries*):
93  Kendrick et al., 2001).

94      In social situations in which fast decision-making is required, it may be
95  advantageous to use social categories rather than relying on individual features.
96  These categories are established through social recognition, defined as the capability
97  of individuals to categorise other individuals into different classes, e.g. familiar vs.
98  unfamiliar, kin vs. non-kin, or dominant vs. subordinate (Gheusi et al., 1994).
99  Categorising individuals can simplify decision-making in complex social environments
100  by reducing the information load (Ghirlanda & Enquist, 2003; Langbein et al., 2023;
101  Lombardi, 2008; Zayan & Vauclair, 1998). Therefore, social recognition might be
102  considered a cognitive shortcut for decision-making. The capability to differentiate
103  between other individuals in two-dimensional images based on social recognition has
104  been shown in several non-human animals (e.g. great apes: Leinwand et al., 2022;
105  capuchin monkeys (*Cebus apella*): Pokorny & de Waal, 2009; horses (*Equus*
106  *caballus*): Lansade et al., 2020; cattle: Coulon et al., 2011; sheep: Peirce et al., 2001).

107      Like many ungulate species, goats are highly vigilant prey animals that rely
108  strongly on their visual sense and auditory sense to detect predators (Adamczyk et al.,
109  2015). As feral goats live in groups with a distinct hierarchy (Shank, 1972), it is likely
110  that they can tell familiar and unfamiliar conspecifics apart (Keil et al., 2012). Goats
111  also show sophisticated social skills, e.g. the ability to follow the gaze direction of a
112  conspecific (Kaminski et al., 2005; Schaffer et al., 2020). It can be assumed that paying

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attention to conspecific head cues may play an important role in a goat's social life as they use head movements to indicate their rank in the hierarchy (Shank, 1972). Goats have also been shown to attribute attention to humans (Nawroth et al., 2015), follow their gaze (Schaffer et al., 2020) and prefer to approach images of smiling humans over images of angry humans (Nawroth & McElligott, 2017), indicating high attention to human facial features. These characteristics make them an ideal candidate species for answering questions regarding their socio-cognitive capacities using looking time paradigms.

In this study, we tested whether a looking time paradigm can be used in dwarf goats to answer biological questions, in this case whether they are capable of spontaneously recognising familiar and unfamiliar con- and heterospecific faces when being presented as two-dimensional images. To do this, we presented the subjects with a visual preference task in which the visual stimuli were presented sequentially and analysed the looking behaviour towards each stimulus. We hypothesised that non-human animals (in this case goats) attribute their visual attention to suddenly appearing objects in their environment (H1). We therefore predicted that our subjects would pay more attention (i.e. higher looking durations) to a video screen presenting a stimulus compared to a white screen (P1). Moreover, we hypothesised that non-human animals show different behavioural responses to two-dimensional images of conspecific compared to images of heterospecific faces, irrespective of familiarity (H2). The preference for looking at conspecifics compared to heterospecifics has been shown in primates (Demaria & Thierry, 1988; Fujita, 1987; Kano & Call, 2014; but see Tanaka, 2007 for an effect in the opposite direction). Sheep, a ruminant species closely related to goats, also preferred conspecific compared to human images when faced with a discrimination task in an enclosed Y-maze (Kendrick et al., 1995). We therefore predicted that the goats in our study would pay more attention (i.e. higher looking durations) to conspecific compared to heterospecific faces, showing a visual preference for conspecific stimuli (P2). We also hypothesised that non-human animals are able to spontaneously recognise familiar and unfamiliar con- and heterospecifics when being presented with their faces as two-dimensional images (H3). The capability to differentiate between familiar and unfamiliar individuals has been demonstrated in several domestic animal species, e.g. llamas (*Lama glama*) (Taylor & Davis, 1996; real humans as stimuli), horses (Lansade et al., 2020; photographs of human faces), cattle (Coulon et al., 2011; photographs of cattle faces) and sheep (Peirce et al., 2000;

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147  photographs of sheep faces, 2001; photographs of human faces). Therefore, we
148  predicted that the subjects in our study would show differential looking behaviour
149  depending on the familiarity of the presented individuals. In particular, we expected
150  that goats would show a visual preference (i.e. higher looking durations) for unfamiliar
151  compared to familiar heterospecific stimuli (see Leinwand et al., 2022; Thieltges et al.,
152  2011 for this preference in great apes and dolphins (*Tursiops truncatus*)), and for
153  familiar compared to unfamiliar conspecific stimuli (see Coulon et al., 2011 for this
154  preference in cattle), resulting in a statistical interaction between the species displayed
155  in the stimuli and the displayed individual's familiarity to our study subjects (P3). We
156  also explored goats' ear position (forward, backward, horizontal, others) during
157  stimulus presentation as ear position has been speculated as being an indicator for
158  differences in arousal and/or valence in goats (Bellegarde et al., 2017; Briefer et al.,
159  2015).
160
161  **Animals, Materials and Methods**
162
163  *Ethical note*
164  The study was waived by the State Agency for Agriculture, Food Safety and Fisheries
165  of Mecklenburg-Vorpommern (Process #7221.3-18196_22-2) as it was not considered
166  an animal experiment in terms of sect. 7, para. 2 Animal Welfare Act. Animal care and
167  all experimental procedures were in accordance with the ASAB/ABS guidelines for the
168  use of animals in research (ASAB Ethical Committee/ ABS Animal Care Committee,
169  2023). All measurements were non-invasive and the experiment did not last longer
170  than ten minutes per day for each individual goat. If the goats had shown signs of a
171  high stress level, the test would have been stopped.
172
173  *Subjects and Housing*
174  Two groups of non-lactating female, one to two years old, Nigerian dwarf goats (group
175  A: 6 subjects, mean age ± SD: 688.2 ± 5.2 d at the start of testing; group B: 6 subjects,
176  472.2 ± 1.2 d at the start of testing) reared at the Research Institute for Farm Animal
177  Biology (FBN) in Dummerstorf participated in the experiment. The animals had
178  previously participated in an experiment with an automated learning device (Langbein
179  et al., 2023) at an earlier age (groups A and B) and in an experiment on prosocial
180  behaviour in goats (unpublished data; group A). Each group was housed in an

181 approximately 15 m$^2$ (4.8 m x 3.1 m) pen consisting of a deep-bedded straw area (3.1

182 m x 3.1 m) and a 0.5 m elevated feeding area (3.1 m x 1.5 m). Each pen was equipped

183 with a hay rack, a round feeder, an automatic drinker, a licking stone, and a wooden

184 podium for climbing. Hay and food concentrate were provided twice a day at 7 am and

185 1 pm, while water was offered ad libitum. Subjects were not food-restricted during the

186 experiments.

187

188 ***Experimental arena and apparatus***

189 The experimental arena was located next to the two home pens. It consisted of three

190 adjoining rooms with 2.1 m high wooden walls connected by doors (Fig. 1). Data

191 collection took place in a testing area (4.5 m x 2 m) divided into two parts (2.25 m x 2

192 m) by a fence that facilitated the separation of single subjects from the rest of the

193 group. The experimental apparatus was inserted into the wall between the testing area

194 and the experimenter booth (2 m x 1.5 m), which was located behind the apparatus

195 and where an experimenter (E1) was positioned during all sessions. The subject in the

196 testing area had no visual contact with E1. Between the different sessions of data

197 collection subjects remained in an adjacent waiting area (6 m x 2.2 m).

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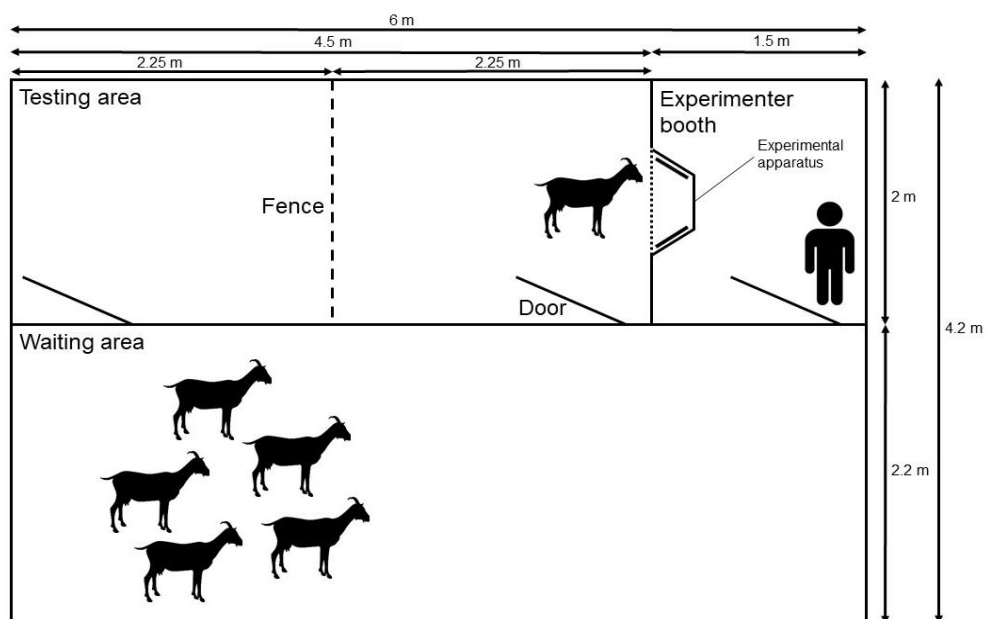


199

200 **Fig. 1** Scheme of the experimental arena, including the testing area, the experimenter

201 booth, the waiting area and the experimental apparatus

202    The experimental apparatus (Fig. 2) was inserted into the wall between the
203    testing area and the experimenter booth at a height of 36 cm above the floor and
204    consisted of two video screens (0.55 m x 0.33 m) mounted on the rear wall of the
205    apparatus. The video screens were positioned laterally so that they were angular
206    (around 45°) to a subject standing in front of the apparatus. Two digital cameras were
207    installed: one (AXIS M1135, Axis Communications, Lund, Sweden) on the ceiling
208    provided a top view of the subject, and one (AXIS M1124, Axis Communications, Lund,
209    Sweden) on the wall separating the two video screens provided a frontal view of the
210    subject. Videos were recorded with a 30 FPS rate. A food bowl, connected to the
211    experimenter booth by a tube, was inserted into the bottom of the apparatus. This
212    allowed E1 to deliver food items without being in visual contact with the tested subject.
213



214

215    **Fig. 2** Experimental apparatus with video screens (VS), cameras (C), food bowl (B)
216    and tube (T)

217

218    *Habituation*

219    The experiment required the handling of the animals by the experimenters (E1 and
220    E2). To this end, they entered the pen, talked to the animals, provided food items
221    (uncooked pasta), and, if possible, touched them. The experimenters stayed in the
222    pen for approximately 30 minutes daily for twelve days (group A) and eleven days

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223 (group B) until each of the animals remained calm when the experimenters entered
224 the pen and could be hand-fed.

225 After this home pen habituation period, the animals were introduced as groups
226 to the experimental arena for approximately 15 minutes per day. On the first two days
227 of this habituation phase, the subjects were allowed to move freely between the waiting
228 area and the testing area, and food was provided in the whole arena. On the third day,
229 the doors between the two areas were temporarily closed and food was provided only
230 at the experimental apparatus with E1 sitting in the experimenter booth and inserting
231 food through the tube into the food bowl, while E2 remained with the animals in the
232 testing area. The video screens of the experimental apparatus were turned off on the
233 first two days of the habituation phase and then turned on only showing white screens.
234 Group habituation lasted for ten sessions for both groups. After these ten sessions, all
235 animals remained calm in the experimental arena, fed out of the food bowl in the
236 experimental apparatus, and were thus transferred to the next habituation phase.

237 In the next habituation phase, all goats were transferred to the experimental
238 arena but only two subjects were introduced to the testing area while the other four
239 group members remained in the waiting area to maintain acoustic and olfactory
240 contact. Each pair was provided with 20 food items over a period of 5 min *via* the tube
241 connecting the food bowl in the apparatus and the experimenter booth. Subjects were
242 immediately reunited with the rest of the group after the separation. Optimal subject
243 groupings were identified over time, as some subjects showed signs of stress when
244 separated in the pair setting. This habituation phase took ten sessions for group A and
245 14 sessions for group B. After this phase, all animals remained calm in the pair setting,
246 fed out of the food bowl in the experimental apparatus, and were thus transferred to
247 the next habituation phase.

248 Finally, subjects were habituated alone for approximately 3 min per day, using
249 the same procedure as for the pair habituation, except that only 10 food items were
250 provided *via* the tube connecting the food bowl in the apparatus and the experimenter
251 booth. This habituation phase took 5 sessions for both groups. Two subjects showed
252 signs of a high stress level (e.g. loud vocalisations, restless wandering, and rejection
253 of feed uptake) during the habituation and were therefore excluded from the
254 experiment. The remaining ten subjects that stayed calm in the testing area and fed
255 out of the food bowl proceeded to the experimental phase during which one subject
256 needed to be excluded at a later stage as it began to show indicators of high stress.

257 ***Experimental procedure***

258

259 <u>Stimuli and stimulus presentation</u>

260 In this experiment, photographs of human and goat faces were used as stimuli. A

261 professional photographer took pictures of the individual goats from both groups and

262 also of four humans, two being familiar to the goats (E1 and E2) and two being

263 unfamiliar to the goats. Familiar humans had almost daily positive interactions with the

264 animals during the habituation phase over at least three months. Familiar and

265 unfamiliar humans were matched for sex (one female, one male each). Each face was

266 photographed in two slightly different orientations: the human faces were rotated

267 slightly to the left and right, and the goat faces were photographed in two different

268 head orientations, provided that both eyes were visible (Fig. 3). This was done to

269 increase the variability of the provided stimuli. Additionally, each picture was tested for

270 its brightness (ImageJ 1.53m, Wayne Rasband and contributors, National Institute of

271 Health, USA, http://imagej.nih.gov/ij, Java 1.8.0-internal (32-bit)) and its size (Corel[®]

272 Photo-Paint X7 (17.1.0.572), © 2014 Corel Corporation, Ottawa, Canada). No

273 difference was found between the goat faces and the human faces with respect to

274 brightness (goats: $231.66 \pm 6.1$ (mean ± SD), humans: $225.91 \pm 6.44$), but the two

275 stimulus categories varied regarding size (goats: $46092.06 \pm 2655.86$ px (mean ± SD),

276 humans: $59317.5 \pm 2260.65$ px). The stimuli were presented as approximately life-

277 sized, in colour, and with a white background. Images were presented either on the

278 left or on the right screen while the other screen remained white. Each test session

279 consisted of a stimulus set of five slides. An initial white slide started the set followed

280 by four slides with a stimulus on either the left or the right side. Four stimulus sets

281 showed human faces and 16 stimulus sets showed goat faces. Each of these sets

282 contained pictures of two familiar and two unfamiliar goats/humans with each

283 goat/human presented only once. The human images were the same for all subjects,

284 while the goat images varied as an individual goat was not allowed to see its own

285 picture as a stimulus. The stimuli were presented on the video screens in a

286 pseudorandomized and counterbalanced order.
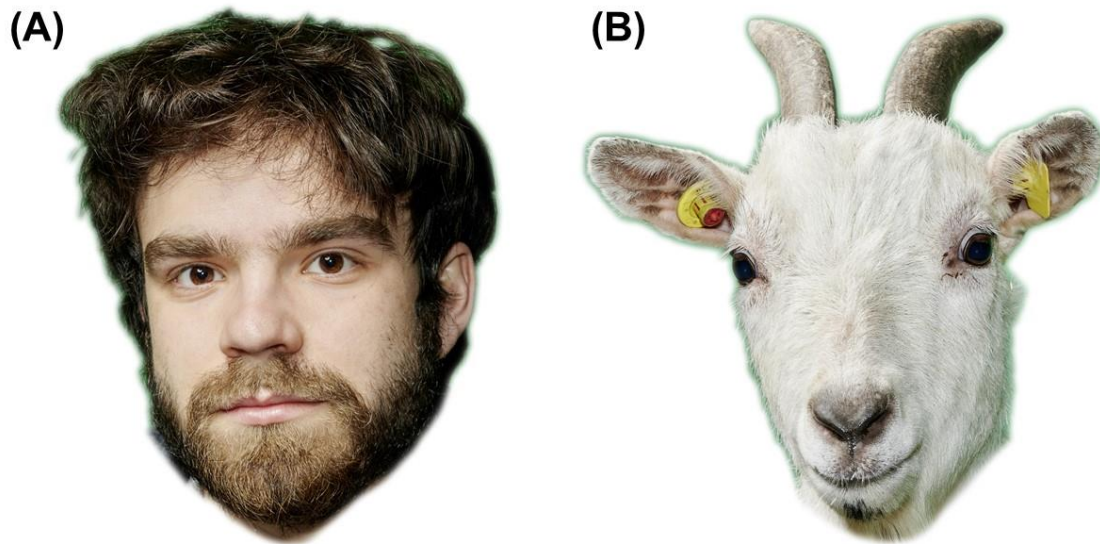
**Fig. 3** Examples of the faces used as stimuli (A) familiar human and (B) goat (familiarity depended on the subject tested)

Data collection

Data collection took place in May and June 2022. Testing started at 9:00 a.m. each day, and each subject completed eight sessions (4 consecutive sessions with goat stimuli, and 4 consecutive sessions with human stimuli with a switch of stimulus species between session 4 and 5) with one session per day. Group A was presented with the goat faces first, group B with the human faces. A session started when the subject was separated from the rest of the group and stood in front of the experimental apparatus. Prior to the stimulus presentation, one to two motivational trials were conducted in which a food item was inserted into the apparatus without any stimulus being presented. Immediately before each stimulus presentation, a food item was inserted into the food bowl. The stimulus presentation lasted for 10 seconds. A test trial was followed by another motivational trial so that motivational trials and test trials alternated until all four stimuli of a set had been presented. The number of motivational trials varied depending on the behaviour of the subject and could be increased, e.g. if the animal was restless at the beginning of the session. Data from the subject that needed to be excluded after the fifth test session remained in the data set.

307 ***Data scoring and analysis***

308

309 <u>Video coding</u>

310 The behaviour of the individual goats was scored using Boris (Friard & Gamba, 2016,

311 Version 7.13), an event logging software for video coding and live observations. For

312 the video coding of the looking behaviour, the recordings from the camera providing a

313 top view of the subject were used. Coding was performed in frame-by-frame mode and

314 the researchers remained blind to the stimulus presentation by covering the video

315 screens of the apparatus during coding. The first look was scored when the subject

316 directed its gaze towards a video screen for the first time in a trial once the head was

317 lifted from the food bowl. Besides the direction of the first look, the looking duration at

318 each video screen was scored. To determine the direction in which the subject was

319 looking, a fictitious line that extends from the middle of the snout (orthogonal to the

320 line connecting both eyes) was drawn (Fig. 4). As this line would align with a binocular

321 focus of the tested subject, it was used as an indicator of a goat directing its attention

322 to a particular screen. The goat's looking behaviour was not scored when the subject

323 was not facing the wall of the testing area in which the apparatus was inserted because

324 then it could not be ensured that it was actually paying attention to the presented

325 stimulus. Video elements in which the goat's face was not visible due to occlusion (e.g.

326 when the subject was sniffing a video screen after moving into the apparatus with both

327 forelegs) were not scored. There was no scoring when the subject's snout was above

328 its eye level because in this case it was assumed that it was looking at the ceiling of

329 the apparatus and not at the video screens or the wall separating the two video

330 screens. There was also no scoring when the subject's snout was perpendicular to the

331 bottom of the apparatus, as in this case it was assumed that the subject was sniffing

332 the bottom of the apparatus with its sight also directed towards it rather than towards

333 the video screens. Inter-observer reliability for the looking duration towards S+ was

334 assessed in a previous stimulus presentation study using the same coding rules and

335 was found to be very high (80 out of 200 trials (40 %) of the videos were coded by two

336 observers; Pearson correlation coefficient (r) = 0.96; p < 0.001).
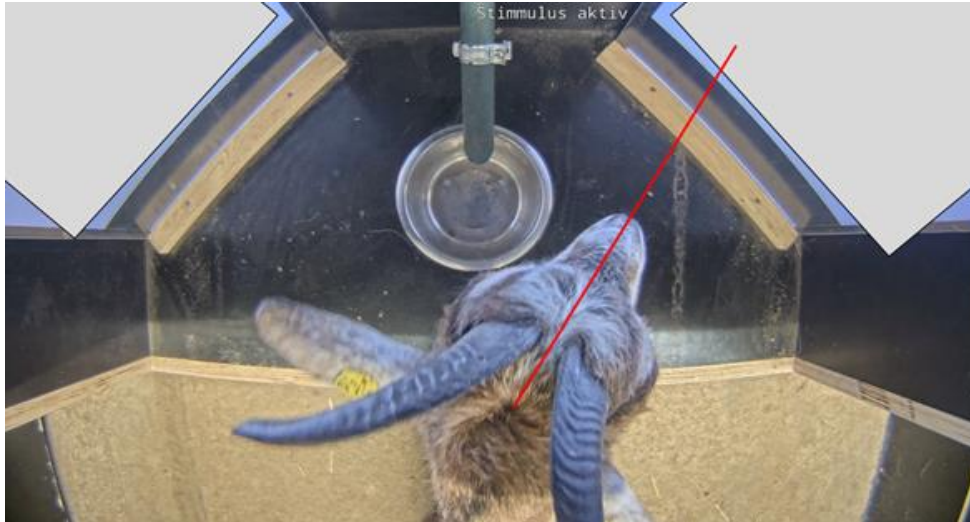
**Fig. 4** Image of the camera providing a top view of the apparatus during the stimulus presentation. Video screens were covered during the video coding to reduce potential biases during video coding. A fictitious line extending from the middle of the snout (red) was used in the blind coding for deciding which video screen the subject was looking at

For the video coding of the ear positions during the stimulus presentation, which was also performed in frame-by-frame mode, recordings from the camera providing a frontal view of the subject were used. We scored four different ear positions (see Boissy et al., 2011; Briefer et al., 2015 for related scoring in goats and sheep): ears oriented forward (tips of both ears pointing forward), backward (tips of both ears pointing backward), horizontal (ear tips perpendicular to the head-rump-axis) and other postures (all ear positions not including the positions mentioned above, i.e. asymmetrical ears or the change between two ear positions). The ear positions were analysed for the entire ten seconds of stimulus presentation, regardless of whether the subjects were looking at the video screens. Video elements in which not both ears (or at least parts of both ears that allowed a precise determination of the ear positions) were visible, were not scored. There was no scoring when the ear position could not be clearly determined, i.e. unclear ear tip positions when the subject was standing further away, even though both ears were visible. All videos were coded by one observer.

Statistical analysis

360 Statistical analysis was carried out in R (R Core Team, 2022, Version 4.2.2).
361 To assess whether subjects looked longer at one of the video screens, the mean
362 looking duration at the video screen presenting a stimulus (S+) and the video screen
363 without a stimulus (S-) for each subject were compared using a Wilcoxon signed-rank
364 test (as data points were not normally distributed). Subsequently, it was analysed how
365 often the first look (FL) was directed towards S+ or S- and the probability of the FL
366 being directed towards S+ compared to S- was calculated (p). Additionally, the odds,
367 representing how much more frequently the FL was directed towards the stimulus than
368 towards the white display, were calculated as follows:

369

370 $$p / (1 - p)$$

371

372 Furthermore, four linear mixed-effects models (R package "blme"; Chung et al.,
373 2013) were set up. The four respective response variables were "looking duration at
374 S+" (out of the total of 10s of stimulus presentation), "Forward_Ratio" (time ears
375 oriented forward divided by the summed-up durations of all four ear positions),
376 "Backward_Ratio" (time ears oriented backward divided by the summed-up durations
377 of all four ear positions) and "Horizontal_Ratio" (time ears oriented horizontal divided
378 by the summed-up durations of all four ear positions).

379 For all models, we checked the residuals of the models graphically for normal
380 distribution and homoscedasticity (R package "performance"; Lüdecke et al., 2021).
381 To meet model assumptions, "looking duration at S+" was log-transformed and the
382 trials in which "looking duration at S+" had a value of zero (n=17) were excluded as
383 this was an indication that subjects might have been distracted. All models included
384 "Stimulus species" (two levels: human, goat), "Stimulus familiarity" (two levels: familiar,
385 unfamiliar) and "Testing order" (two levels: first human stimuli, first goat stimuli) as
386 fixed effects. We also tested for an interaction effect including "Stimulus species" and
387 "Stimulus familiarity". Repeated measurements "Session" (1-8) per "Subject" (identity
388 of the goat) were defined as nested effects. We followed a full model approach, i.e.,
389 we set up a maximum model that we present and interpret (Forstmeier & Schielzeth,
390 2011). First, we calculated the global p-value (between the maximum and null model)
391 using parametric bootstraps (1,000 bootstrap samples, R package "pbkrtest"; Halekoh
392 & Højsgaard, 2014). If that model reached a low p-value, we tested each of the

393  predictor variables (including the interaction) singly by comparing the full model to the
394  one omitting this predictor. P-values calculated with parametric bootstrap tests give
395  the fraction of simulated likelihood ratio test (LRT) statistical values that are larger or
396  equal to the observed LRT value. This test is more adequate than the raw LRT
397  because it does not rely on large-sample asymptotic analysis and correctly takes the
398  random-effects structure into account (Halekoh & Højsgaard, 2014). Moreover, it was
399  tested whether there was an increase in the looking duration towards S+ between
400  session 4 and session 5, due to a dishabituation effect in the subjects caused by the
401  switch of the presented stimulus species. To achieve this, the mean looking durations
402  towards S+ in both sessions were calculated for each subject and then compared by
403  performing a paired t-test. Type 1 error rate was controlled at a level of $p = 0.05$ for all
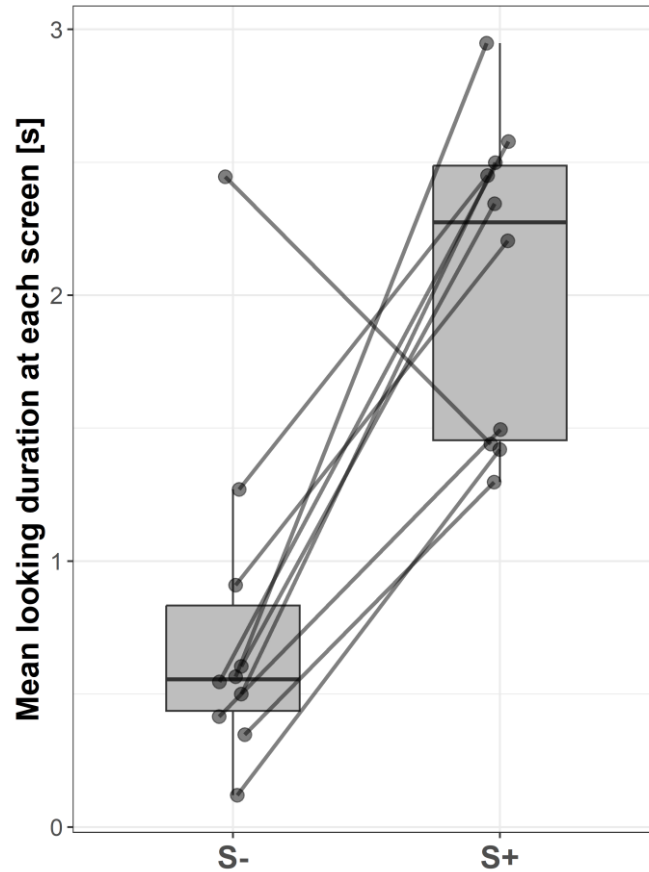404  tests.
405
406  **Results**
407
408  *Preference for S+ over S- regarding looking duration*
409  With their mean duration, subjects looked significantly longer at S+ (2.27 ± 1.03 s;
410  median ± IQR) compared to S- (0.56 ± 0.4 s; Wilcoxon signed-rank test: V = 53; $p =$
411  0.006; Fig. 5).

**Fig. 5** Boxplots showing the mean looking durations at the video screen without a stimulus (S-) and the video screen presenting a stimulus (S+) of all subjects across all trials. Lines indicate data points from the same individual

*Preference for S+ over S- regarding first look*

In 264 of the 301 trials (86.6%) in which the animals were attentive to the video screens (4 trials were excluded in which the animals neither looked at the left nor the right video screen), the FL was directed towards S+. Therefore, the probability of the FL being directed towards S+ was six times more likely than towards S-.

*Factors affecting looking duration at S+*

Regarding the looking duration model, we found no substantial interaction effect between the factors "Stimulus species" and "Stimulus familiarity" ($p = 0.27$). Across all test trials, goats looked longer at goat faces compared to human faces ($p = 0.027$, Fig. 6). The familiarity of the stimulus subject and the testing order did not substantially affect their looking duration at S+ (both $p \geq 0.48$, Fig. 6).

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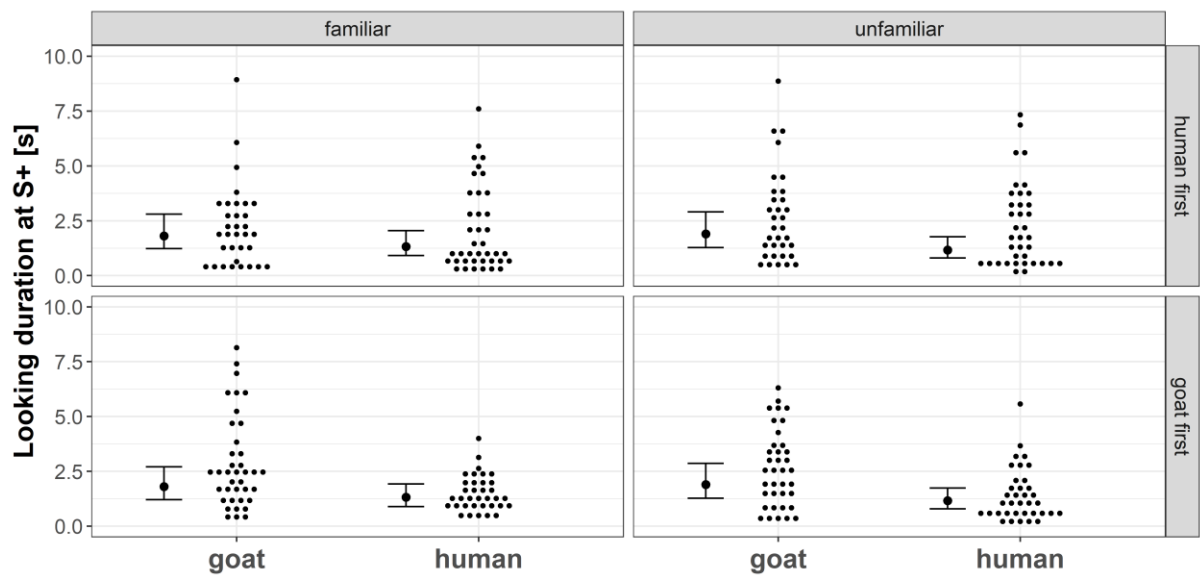
**Fig. 6** Small dots represent the looking duration at the video screen presenting a stimulus (S+) across species, familiarity, and testing order. Larger black dots are the corresponding model estimates for each condition, and thin black lines and whiskers are the 95 % confidence intervals of the maximum model (including the main effects and interactions)

*Differences in looking duration when stimulus species switched (Session 4 vs. Session 5)*

Subjects looked longer at S+ during session 5 (3.28 ± 1.5 s; mean ± SD) compared to session 4 (1.58 ± 0.77 s; paired t-test: t = -1.70; p = 0.014, Fig. 7) when the stimulus species switched from human to goat or vice versa.
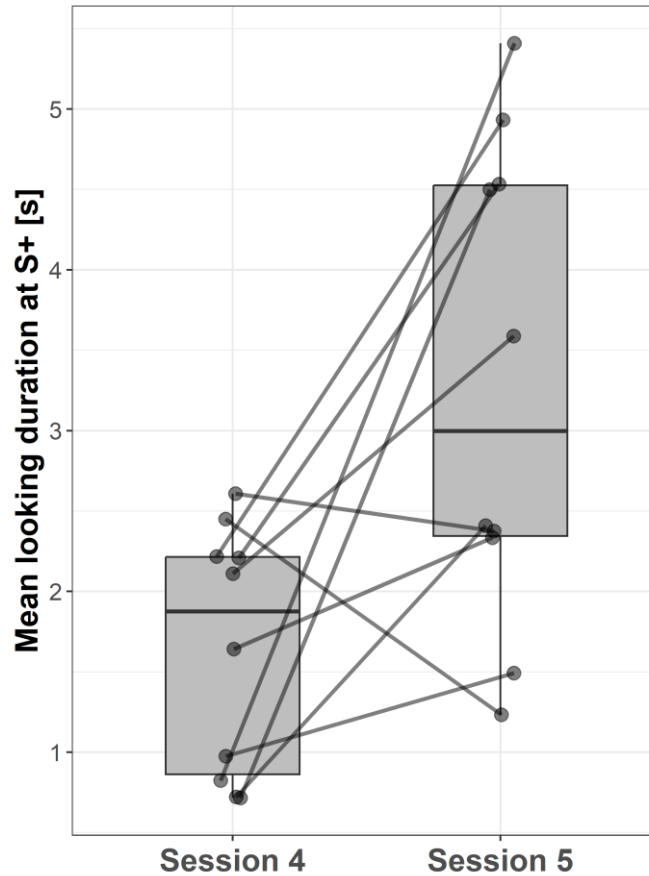
Fig. 7 Boxplots showing the mean looking durations at S+ in sessions 4 and 5 (stimulus switch from human to goat or vice versa) for all subjects. Lines indicate data points from the same individual

*Factors affecting ear positions during stimulus presentation*

Regarding the ear position, none of the three models revealed a significant interaction effect between "Stimulus species" and "Stimulus familiarity" (all $p \geq 0.32$). We found no statistically supported differences in the ratios of the three ear positions for the fixed factors "Stimulus species" (all $p \geq 0.57$), "Stimulus familiarity" (all $p \geq 0.44$) and "Testing order" (all $p \geq 0.61$).

**Discussion**

In this study, we tested whether a looking time paradigm can be used to answer questions on recognition capacities in dwarf goats, in this case whether they are capable of recognising familiar and unfamiliar con- and heterospecific faces when being presented as two-dimensional images. To assess visual attention (via looking time) and arousal (via ear positions), we measured the goats' looking behaviour towards the stimuli and their ear positions during the trial. Our results show that goats differ in their behavioural responses when presented with 2D images of either con- or heterospecifics, showing a visual preference for goat faces. However, their response did not differ between familiar and unfamiliar individuals (irrespective of species), suggesting that goats either cannot spontaneously assign social recognition categories to 2D images or were equally motivated to pay close attention to both categories (but for different reasons). These findings are partly in contrast to related research on goats and other domestic ungulate species (Coulon et al., 2011; Langbein et al., 2023) and thus raise questions about the comparability of test designs.

As predicted (P1), goats paid more attention to a video screen presenting a stimulus (S+) compared to a white screen (S-), supporting our hypothesis that non-human animals (in this case goats) attribute their visual attention to suddenly appearing objects in their environment (H1). Additionally, 86.6 % of the first looks were directed towards S+ compared to S-. These results indicate that the subjects were attentive with regard to the stimuli presented and therefore is good evidence that the design of our looking time paradigm is an appropriate experimental setup to address the visual sense of small ungulates.

As predicted (P2), subjects paid more attention to goat compared to human faces, supporting our hypothesis that non-human animals show different behavioural responses to two-dimensional images of conspecific compared to heterospecific faces, irrespective of familiarity (H2). This aligns with Kendrick et al. (1995), who found that sheep preferred conspecifics over humans in a visual discrimination task, and with studies conducted with rhesus macaques (Demaria & Thierry, 1988; Fujita, 1987). There are several possible reasons why the goats in our study paid more visual attention to the conspecific stimuli. One possible explanation might be that conspecific stimuli may generally convey more biologically relevant information, such as the identity, sex, age, status in the hierarchy or even the emotional state of a conspecific. This principle should similarly apply to goats, given their highly social nature, either as

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484  an inherent trait or influenced by developmental factors. In our study, limited exposure
485  to humans prior to the study might also have resulted in a bias towards conspecifics.
486  It would therefore be interesting to see whether hand-reared goats would also show a
487  conspecific bias. We cannot fully exclude that participating in other experiments might
488  have influenced the behaviour of our subjects - especially as the subjects from our
489  study participated in an experiment with an automated learning device with
490  photographs being presented on a computer display. However, we never observed
491  that our subjects showed the learned response from this previous experiment (using
492  the video screen as a touchscreen with their snout to indicate a choice regarding a
493  photograph) so that it can be considered less likely that our subjects have transferred
494  their learned responses and associated behaviours to our study. Another possible
495  reason for the observed visual preference for conspecific faces in goats might be that
496  the sight of a conspecific might work as a stress buffer during the isolation in the test
497  trials as has been shown for sheep when being isolated from their social group (da
498  Costa et al., 2004). Da Costa (2004) tested whether sheep in social isolation would
499  show reduced indications of stress when being presented with an image of a
500  conspecific compared to images of goats or inverted triangles and found that seeing a
501  conspecific face in social isolation significantly reduced behavioural, autonomic and
502  endocrine indices of stress. As feral goats and sheep have comparable social
503  structures it is reasonable to assume that images of conspecifics might likewise have
504  positive effects on the tested subjects in our study. Additional assessment of stress
505  parameters, such as heart rate (variability) or cortisol concentration, is recommended
506  (see e.g. da Costa et al., 2004).

507  Alternatively, a possible reason for the shorter looking durations at the human
508  stimuli might be due to avoidance of the human face images, as the presented humans
509  might be perceived as possible predators (Davidson et al., 2014). This might have led
510  to behavioural responses aimed at reducing the time the human images can be
511  observed, e.g. by moving away from the experimental apparatus. In sheep,  human
512  eye contact altered behaviour compared to no human eye contact, resulting in more
513  locomotor activity and urination when being stared at, but no differences in fear-related
514  behaviours, such as escape attempts (Beausoleil et al., 2006). This might imply that
515  human eye contact can be interpreted as a warning cue for sheep (Beausoleil et al.,
516  2006). Goats, in our study, might thus have simply avoided the human image (and
517  gaze) rather than showing an active preference for goat images.

Additional support for H2 is provided by the finding that the subjects in our study also looked longer at the stimuli in session 5 compared to session 4 when the presented stimulus species was switched from human to goat or vice versa. This switch corresponds to a habituation-dishabituation paradigm. In this paradigm, a habituation stimulus is presented to the subject either for a long period or over several short periods (habituation period) and is then replaced by a novel stimulus in the dishabituation period (Kavšek & Bornstein, 2010). In habituation-dishabituation paradigms, the subject's attention to the habituation stimulus is expected to decrease during the habituation period, but then to increase in the dishabituation period when a novel stimulus (that the subject is able to distinguish from the previous one) is presented (Kavšek & Bornstein, 2010). As our study found longer looking durations at the novel stimulus species compared to the old one, it can be assumed that the subjects noticed that the stimuli had changed and were therefore able to discriminate between conspecific and heterospecific stimuli. This additionally supports our primary findings regarding the capability to discriminate between con- and heterospecifics when presented as two-dimensional images.

Contrary to our third prediction (P3), we found no statistical support for differences in the looking behaviour with respect to the familiarity of the depicted individuals. Consequently, we have to reject the hypothesis that non-human animals (in this case goats) are able to spontaneously recognise familiar and unfamiliar con- and heterospecifics when being presented with their faces as two-dimensional images (H3). There are several possible reasons, of varying likelihood, that might explain this finding. One possibility is that the subjects were simply not able to differentiate between familiar and unfamiliar individuals because they did not form the concept of familiar or unfamiliar individuals associated with social recognition in general. Alternatively, visual head cues alone might not be sufficient for goats to form these categories. Keil et al. (2012) even found that goats don't necessarily need to see a conspecific's head to discriminate between group members and goats from another social group. In contrast to this, results from other ruminants, such as cattle (Coulon et al., 2011) and sheep (Peirce et al., 2000, 2001), have shown that a set of ruminant species have the capability to form this concept using two-dimensional head cues in a visual discrimination task. Langbein et al. (2023) also found some evidence that goats are able to associate two-dimensional representations of conspecifics with real animals in a visual discrimination task. It is therefore surprising to see that the subjects

in our study did not show differential looking behaviour with respect to the familiarity of the individuals presented. It might also be possible that subjects were indeed able to differentiate between the categories of stimulus familiarity, but had the same level of motivation (but for different reasons) to pay close attention to both categories, resulting in similar looking durations. The different reasons for looking at either familiar or unfamiliar con- or heterospecifics (e.g. novelty (Fantz, 1964; Tulving & Kroll, 1995), threat perception, individual recognition, positive associations or social buffering (for a more detailed discussion see Rault, 2012)) might therefore have compensated for each other and could, ultimately, have led to the absence of a visual preference for a specific category in this study. This assumption also seems plausible when considering the results of Demaria & Thierry (1988), who presented both images of familiar and unfamiliar conspecifics to stump-tailed macaques. They did not find a difference in the looking durations at both stimulus categories but did observe that when looking at the image of a familiar conspecific, some subjects turned back to look at the social group to which the stimulus macaque belonged to. This pattern was never observed for unfamiliar conspecifics, which might indicate that the subjects did indeed distinguish between familiar and unfamiliar individuals. However, this capability could not be inferred from the looking durations at the images *per se* as they also showed no preference for any of the categories.

We did not find statistical support for an association between the presented stimulus species or the familiarity of the depicted individuals and the amount of time spent with the ears in a specific position. A higher percentage of the ears in a forward position might be associated with situations that lead to high arousal and/or increased attention in goats (Bellegarde et al., 2017; Briefer et al., 2015). Thus, it seemed probable that the subjects in our study would show a higher percentage of ears in a forward position when being presented with the stimulus species that they looked longer at (here, goat faces). We can only speculate as to why this was not the case in our study. One possibility could be that the "ear forward position", as well as the "ears backward position", is not solely associated with the level of arousal or attention in goats, but also with the valence of the situation experienced by the animal (Bellegarde et al., 2017; Briefer et al., 2015). As we cannot safely infer from our looking duration data that subjects actually perceived the two-dimensional images of the stimulus subjects as representations of their real, three-dimensional counterparts, we cannot make good assumptions about the particular levels of valence and arousal that our

stimuli might have elicited in our focal subjects, making a comparison problematic. It is also possible that the 2D images presented as stimuli did not evoke arousal strong enough to make the ear position a good behavioural parameter. Therefore, the ear position during stimulus presentation does not seem to be an appropriate parameter for testing the attention of goats in our looking time paradigm.

This study has shown that looking time paradigms can be used to test discrimination abilities and visual preferences in goats, provided that the results are interpreted with caution. Thus, it lays the foundation for the work on related research questions using this methodology. As this study was only partly able to demonstrate social visual preferences in goats, further studies are needed to identify the factors that dominantly direct the attention of goats. Therefore, different social visual stimuli other than solely head cues could be used, e.g. full body images of a con- or heterospecific or even videos. In addition, different sensory modalities could be addressed, e.g. by pairing visual with acoustic or olfactory cues. Such a cross-modal approach could provide subjects with a more holistic, yet highly controlled, representation of other individuals. Further looking time paradigm studies in goats should not only focus on their behavioural responses to specific stimuli, but should also consider adding the measurement of physiological parameters that indicate stress. For example, measuring the heart rate or heart rate variability (e.g. Langbein et al., 2004) or the concentration of cortisol (da Costa et al., 2004) could help to obtain a more comprehensive picture of how goats perceive specific 2D stimuli. In terms of technical advances, eye-tracking could also be considered to provide more accurate estimates of visual attention in focal subjects (e.g. Gao et al., 2022; Shepherd & Platt, 2008; Völter & Huber, 2021). In the future, this looking time approach could be also used to assess the interplay between cognition and emotions, e.g. to assess attention biases associated with the affective state of an animal (Crump et al., 2018). Given that appropriate stimuli can be identified, an automatised looking time paradigm would offer an efficient approach to assess husbandry conditions, not only experimentally, but also on-farm.

**Conclusion**

The looking time paradigm presented here appears to be generally suitable for testing visual preferences in dwarf goats, while assessing the concept of familiarity may require better controls for confounding factors to disentangle the different motivational

factor associated with the presented stimuli. Goats showed a visual preference for conspecifics when discriminating between two-dimensional images of goats and humans. This is consistent with previous findings in macaques (Demaria & Thierry, 1988; Fujita, 1987) and sheep (Kendrick et al., 1995). In contrast to previous research in a variety of species (e.g. great apes: Leinwand et al., 2022; capuchin monkeys: Pokorny & de Waal, 2009; cattle: Coulon et al., 2011; horses: Lansade et al., 2020; sheep: Peirce et al., 2001), we found no attentional differences when goats were presented with two-dimensional images of familiar and unfamiliar individuals which calls into question the comparability of results obtained with different experimental designs.

**Conflict of interest disclosure**

Christian Nawroth is recommender of PCI Animal Science. The authors declare that they comply with the PCI rule of having no financial conflicts of interest in relation to the content of the article.

**Author contribution section**

JD – data curation, formal analysis, investigation, methodology, writing – original draft preparation, writing – review & editing

SL – data curation, investigation

AE – formal analysis, visualisation, writing – review & editing

CN – conceptualisation, formal analysis, methodology, project administration, supervision, visualisation, writing – original draft preparation, writing – review & editing

**Data availability statement**

Raw data and R script can be found here: https://osf.io/nepwu/

**Acknowledgements**

We would like to thank the staff of the Experimental Animal Facility Pygmy Goat at the Research Institute for Farm Animal Biology in Dummerstorf, Germany, for taking care of the animals. Special thanks go to Michael Seehaus for technical support.

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