1 **Goats who stare at video screens – assessing behavioural responses of goats**

2 **towards images of familiar and unfamiliar con- and heterospecifics**

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16 **Abstract**

17 Many cognitive paradigms rely on active decision-making, creating participation biases

18 (e.g. subjects may lack motivation to participate in the training) and once-learned

19 contingencies may bias the outcomes of subsequent similar tests. We here present a

20 looking time approach to study goat perception and cognition, without the need to

21 extensively train animals and no reliance on learned contingencies. In our looking time

22 paradigm, we assessed the attention of 10 female dwarf goats (*Capra hircus*) towards

23 2D visual stimuli which were images of familiar and unfamiliar con- and heterospecifics

24 (i.e. goats and humans) using an experimental apparatus containing two video

25 screens. Spontaneous behavioural reactions to the presented stimuli, including the

26 looking behaviour and the time spent with the ears in different positions were analysed

27 using linear mixed-effects models. We found that goats looked longer at the video

28 screen presenting a stimulus compared to the screen that remained white. Goats

29 looked longer at images depicting other goats compared to humans, while their looking

30 behaviour did not significantly differ when being confronted with familiar vs. unfamiliar

31 individuals. We did not find statistical support for an association between the ear

32 positions and the presented stimuli. Our findings indicate that goats are capable of

33 discriminating between two-dimensional con- and heterospecific faces, but also raise

34 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

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

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 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 goats 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 goats 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; photographs of sheep faces, 2001; photographs of

human faces). Therefore, we predicted that the subjects in our study would show differential looking behaviour depending on the familiarity of the presented individuals. In particular, we expected that goats would show a visual preference (i.e. higher looking durations) for unfamiliar compared to familiar heterospecific stimuli (see Leinwand et al., 2022; Thieltges et al., 2011 for this preference in great apes and dolphins (*Tursiops truncatus*)), and for familiar compared to unfamiliar conspecific stimuli (see Coulon et al., 2011 for this preference in cattle), resulting in a statistical interaction between the species displayed in the stimuli and the displayed individual's familiarity to our study subjects (P3). We also explored goats' ear position (forward, backward, horizontal, others) during stimulus presentation as ear position has been speculated as being an indicator for differences in arousal and/or valence in goats (Bellegarde et al., 2017; Briefer et al., 2015).

Animals, Materials and Methods

Ethical note

The study was waived by the State Agency for Agriculture, Food Safety and Fisheries of Mecklenburg-Vorpommern (Process #7221.3-18196_22-2) as it was not considered an animal experiment in terms of sect. 7, para. 2 Animal Welfare Act. Animal care and all experimental procedures were in accordance with the ASAB/ABS guidelines for the use of animals in research (ASAB Ethical Committee/ ABS Animal Care Committee, 2023). All measurements were non-invasive and the experiment did not last longer than ten minutes per day for each individual goat. If the goats had shown signs of a high stress level, the test would have been stopped.

Subjects and Housing

Two groups of non-lactating female, one to two years old, Nigerian dwarf goats (group A: 6 subjects, mean age ± SD: 688.2 ± 5.2 d at the start of testing; group B: 6 subjects, 472.2 ± 1.2 d at the start of testing) reared at the Research Institute for Farm Animal Biology (FBN) in Dummerstorf participated in the experiment. The animals had previously participated in an experiment with an automated learning device (Langbein et al., 2023) at an earlier age (groups A and B) and in an experiment on prosocial behaviour in goats (unpublished data; group A). Each group was housed in an approximately 15 m^2 (4.8 m x 3.1 m) pen consisting of a deep-bedded straw area (3.1

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

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

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

184 1 pm, while water was offered ad libitum. Subjects were not food-restricted during the

185 experiments.

186

187 ***Experimental arena and apparatus***

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

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

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

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

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

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

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

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

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

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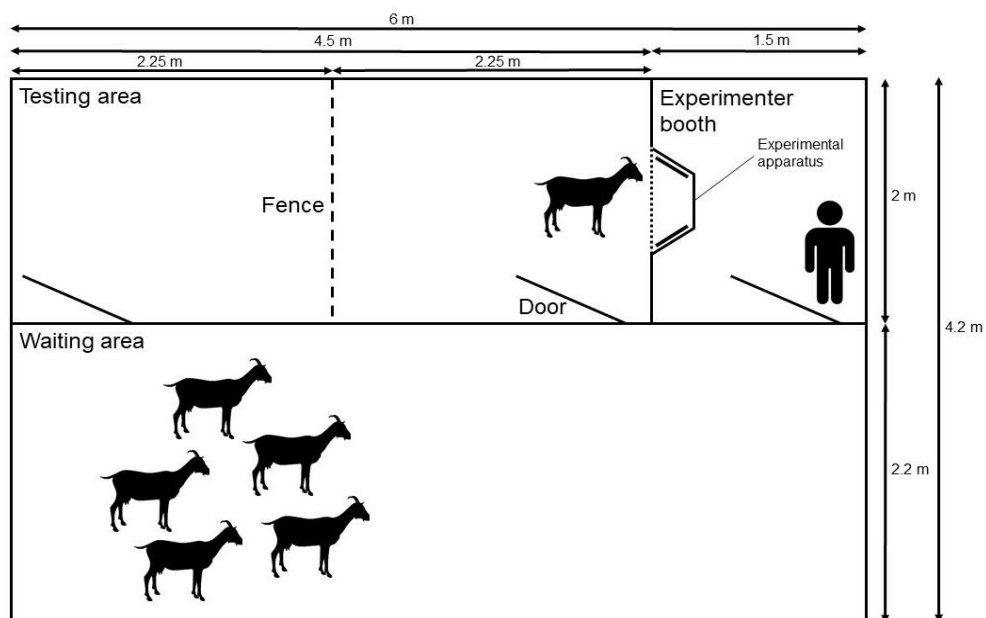
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199 **Fig. 1** Scheme of the experimental arena, including the testing area, the experimenter

200 booth, the waiting area and the experimental apparatus

201   The experimental apparatus (Fig. 2) was inserted into the wall between the

202   testing area and the experimenter booth at a height of 36 cm above the floor and

203   consisted of two video screens (0.55 m x 0.33 m) mounted on the rear wall of the

204   apparatus. The video screens were positioned laterally so that they were angular

205   (around 45°) to a subject standing in front of the apparatus. ==Subjects standing in front==

206   ==of the apparatus were considered to look approximately at the centre of the screens.==

207   Two digital cameras were installed: one (AXIS M1135, Axis Communications, Lund,

208   Sweden) on the ceiling provided a top view of the subject, and one (AXIS M1124, Axis

209   Communications, Lund, Sweden) on the wall separating the two video screens

210   provided a frontal view of the subject. Videos were recorded with a 30 FPS rate. A

211   food bowl, connected to the experimenter booth by a tube, was inserted into the bottom

212   of the apparatus. This allowed E1 to deliver food items without being in visual contact

213   with the tested subject.

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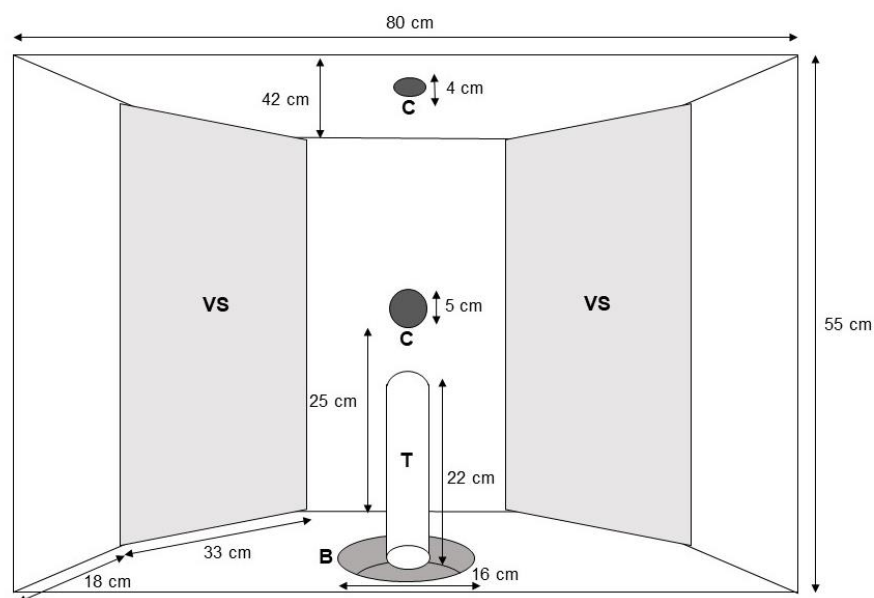
Fig. 2 Experimental apparatus with video screens (VS), cameras (C), food bowl (B)

217   and tube (T)

218

219   *Habituation*

220   The experiment required the handling of the animals by the experimenters (E1 and

221   E2). To this end, they entered the pen, talked to the animals, provided food items

222   (uncooked pasta), and, if possible, touched them. The experimenters stayed in the

223 pen for approximately 30 minutes daily for twelve days (group A) and eleven days
224 (group B) until each of the animals remained calm when the experimenters entered
225 the pen and could be hand-fed.

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

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

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

256 out of the food bowl proceeded to the experimental phase during which one subject

257 needed to be excluded at a later stage as it began to show indicators of high stress.

258

259 ***Experimental procedure***

260

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

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

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

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

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

266 animals (feeding them with dry pasta, if possible touching and gently stroking them)

267 during the habituation phase over at least three months (once a day, five days per

268 week). Familiar and unfamiliar humans were matched for sex (one female, one male

269 each). Each face was photographed in two slightly different orientations: the human

270 faces were rotated slightly to the left and right, and the goat faces were photographed

271 in two different head orientations, provided that both eyes were visible (Fig. 3). This

272 was done to increase the variability of the provided stimuli. Additionally, each picture

273 was tested for its brightness (ImageJ 1.53m, Wayne Rasband and contributors,

274 National Institute of Health, USA, http://imagej.nih.gov/ij, Java 1.8.0-internal (32-bit))

275 and its size (Corel® Photo-Paint X7 (17.1.0.572), © 2014 Corel Corporation, Ottawa,

276 Canada). No difference was found between the goat faces and the human faces with

277 respect to brightness (goats: 231.66 ± 6.1 (mean ± SD), humans: 225.91 ± 6.44), but

278 the two stimulus categories varied regarding size (goats: 46092.06 ± 2655.86 px

279 (mean ± SD), humans: 59317.5 ± 2260.65 px). The stimuli were presented as

280 approximately life-sized, in colour, and with a white background. Images were

281 presented either on the left or on the right screen while the other screen remained

282 white. Each test session consisted of a stimulus set of five slides. An initial white slide

283 started the set followed by four slides with a stimulus on either the left or the right side.

284 Four stimulus sets showed human faces and 16 stimulus sets showed goat faces.

285 Each of these sets contained pictures of two familiar and two unfamiliar goats/humans

286 with each goat/human presented only once. The human images were the same for all

287 subjects, while the goat images varied as an individual goat was not allowed to see its

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

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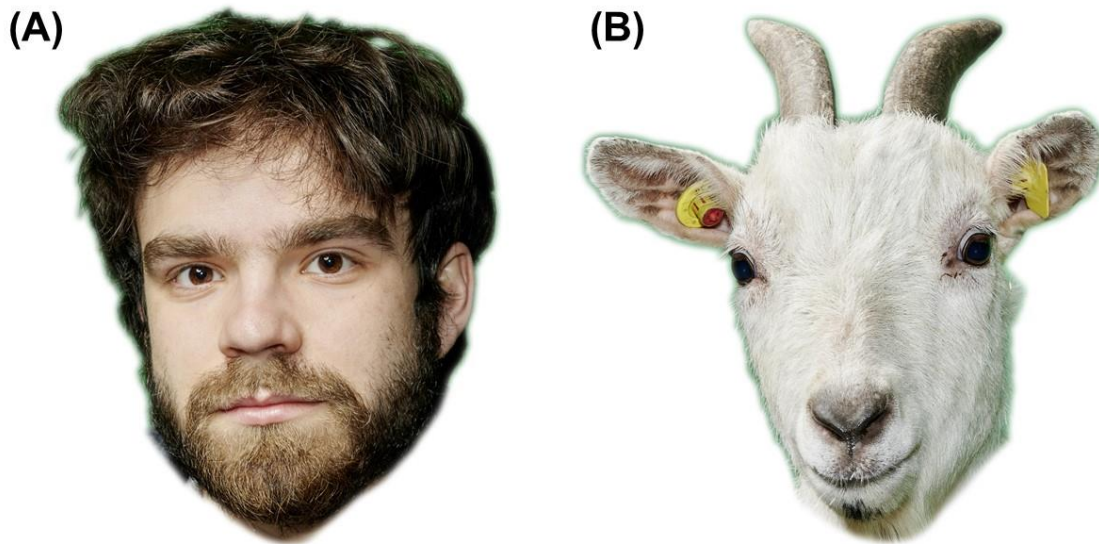
Fig. 3 Examples of the faces used as stimuli (A) familiar human and (B) goat (familiarity depended on the subject tested)

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 for 10 seconds afterwards. 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.

11

Data scoring and analysis

Video coding

The behaviour of the individual goats was scored using Boris (Friard & Gamba, 2016, Version 7.13), an event logging software for video coding and live observations. For the video coding of the looking behaviour, the recordings from the camera providing a top view of the subject were used. Coding was performed in frame-by-frame mode and the researchers remained blind to the stimulus presentation by covering the video screens of the apparatus during coding. The first look was scored when the subject directed its gaze towards a video screen for the first time in a trial once the head was lifted from the food bowl. Besides the direction of the first look, the looking duration at each video screen was scored. To determine the direction in which the subject was looking, a fictitious line that extends from the middle of the snout (orthogonal to the line connecting both eyes) was drawn (Fig. 4). As this line would align with a binocular focus of the tested subject, it was used as an indicator of a goat directing its attention to a particular screen. The goat's looking behaviour was not scored when the subject was not facing the wall of the testing area in which the apparatus was inserted because then it could not be ensured that it was actually paying attention to the presented stimulus. Video elements in which the goat's face was not visible due to occlusion (e.g. when the subject was sniffing a video screen after moving into the apparatus with both forelegs) were not scored. There was no scoring when the subject's snout was above its eye level because in this case it was assumed that it was looking at the ceiling of the apparatus and not at the video screens or the wall separating the two video screens. There was also no scoring when the subject's snout was perpendicular to the bottom of the apparatus, as in this case it was assumed that the subject was sniffing the bottom of the apparatus with its sight also directed towards it rather than towards the video screens. Inter-observer reliability for the looking duration towards S+ was assessed in a previous stimulus presentation study using the same coding rules and was found to be very high (80 out of 200 trials (40%) of the videos were coded by two observers; Pearson correlation coefficient (r) = 0.96; $p < 0.001$).
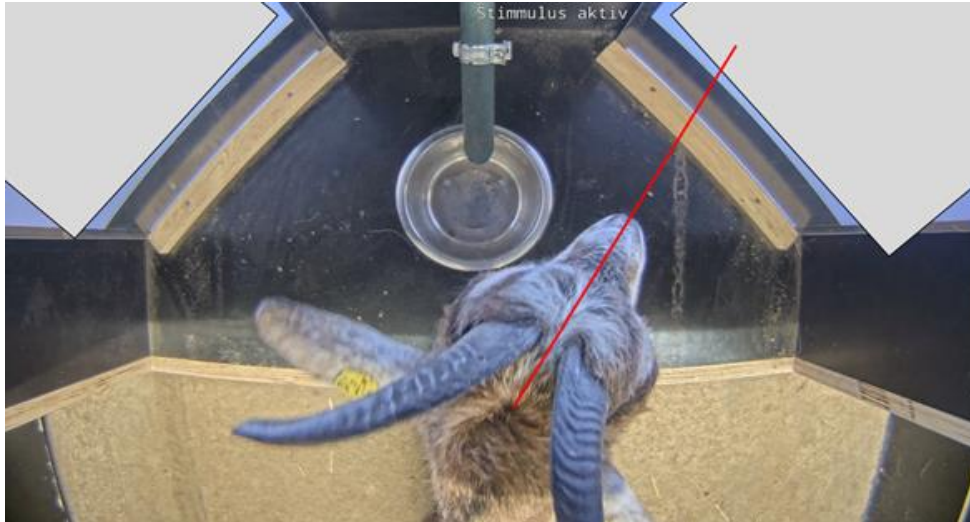
Fig. 4 Image of the camera providing a top view of the apparatus during the stimulus presentation. Video screens were covered during the video coding to reduce potential biases during video coding. A fictitious line extending from the middle of the snout (red) was used in the blind coding for deciding 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. Inter-observer reliability for the duration of ears in the respective positions was found to be high (32 out of 305 trials (11%) of the videos were coded by two observers; Pearson correlation coefficient (r) = 0.85; $p < 0.001$).

Statistical analysis

366 Statistical analysis was carried out in R (R Core Team, 2022, Version 4.2.2).

367 To assess whether subjects looked longer at one of the video screens, the mean

368 looking duration at the video screen presenting a stimulus (S+) and the video screen

369 without a stimulus (S-) for each subject were compared using a Wilcoxon signed-rank

370 test (as data points were not normally distributed). Subsequently, it was analysed how

371 often the first look (FL) was directed towards S+ or S- and the probability of the FL

372 being directed towards S+ compared to S- was calculated (p). Additionally, the odds,

373 representing how much more frequently the FL was directed towards the stimulus than

374 towards the white display, were calculated as follows:

375

376 $$p \, / \, (1 - p)$$

377

378 Furthermore, four linear mixed-effects models (R package "blme"; Chung et al.,

379 2013) were set up. The four respective response variables were "looking duration at

380 S+" (out of the total of 10s of stimulus presentation), "Forward_Ratio" (time ears

381 oriented forward divided by the summed-up durations of all four ear positions),

382 "Backward_Ratio" (time ears oriented backward divided by the summed-up durations

383 of all four ear positions) and "Horizontal_Ratio" (time ears oriented horizontal divided

384 by the summed-up durations of all four ear positions).

385 For all models, we checked the residuals of the models graphically for normal

386 distribution and homoscedasticity (R package "performance"; Lüdecke et al., 2021).

387 To meet model assumptions, "looking duration at S+" was log-transformed and the

388 trials in which "looking duration at S+" had a value of zero (n=17) were excluded as

389 this was an indication that subjects might have been distracted. All models included

390 "Stimulus species" (two levels: human, goat), "Stimulus familiarity" (two levels: familiar,

391 unfamiliar) and "Testing order" (two levels: first human stimuli, first goat stimuli) as

392 fixed effects. We also tested for an interaction effect including "Stimulus species" and

393 "Stimulus familiarity". Repeated measurements "Session" (1-8) per "Subject" (identity

394 of the goat) were defined as nested effects. We followed a full model approach, i.e.,

395 we set up a maximum model that we present and interpret (Forstmeier & Schielzeth,

396 2011). First, we calculated the global p-value (between the maximum and null model)

397 using parametric bootstraps (1,000 bootstrap samples, R package "pbkrtest"; Halekoh

398 & Højsgaard, 2014). If that model reached a low p-value, we tested each of the

399   predictor variables (including the interaction) singly by comparing the full model to the
400   one omitting this predictor. P-values calculated with parametric bootstrap tests give
401   the fraction of simulated likelihood ratio test (LRT) statistical values that are larger or
402   equal to the observed LRT value. This test is more adequate than the raw LRT
403   because it does not rely on large-sample asymptotic analysis and correctly takes the
404   random-effects structure into account (Halekoh & Højsgaard, 2014). Moreover, it was
405   tested whether there was an increase in the looking duration towards S+ between
406   session 4 and session 5, due to a dishabituation effect in the subjects caused by the
407   switch of the presented stimulus species. To achieve this, the mean looking durations
408   towards S+ in both sessions were calculated for each subject and then compared by
409   performing a paired t-test. Type 1 error rate was controlled at a level of $p = 0.05$ for all
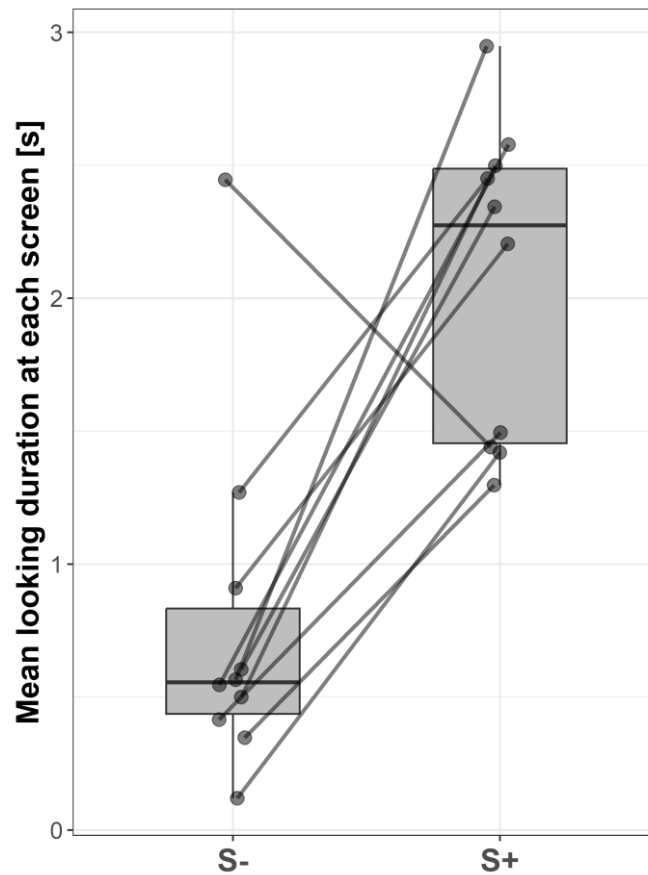410   tests.
411
412   **Results**
413
414   ***Preference for S+ over S- regarding looking duration***
415   With their mean duration, subjects looked significantly longer at S+ (2.27 ± 1.03 s;
416   median ± IQR) compared to S- (0.56 ± 0.4 s; Wilcoxon signed-rank test: V = 53; p =
417   0.006; Fig. 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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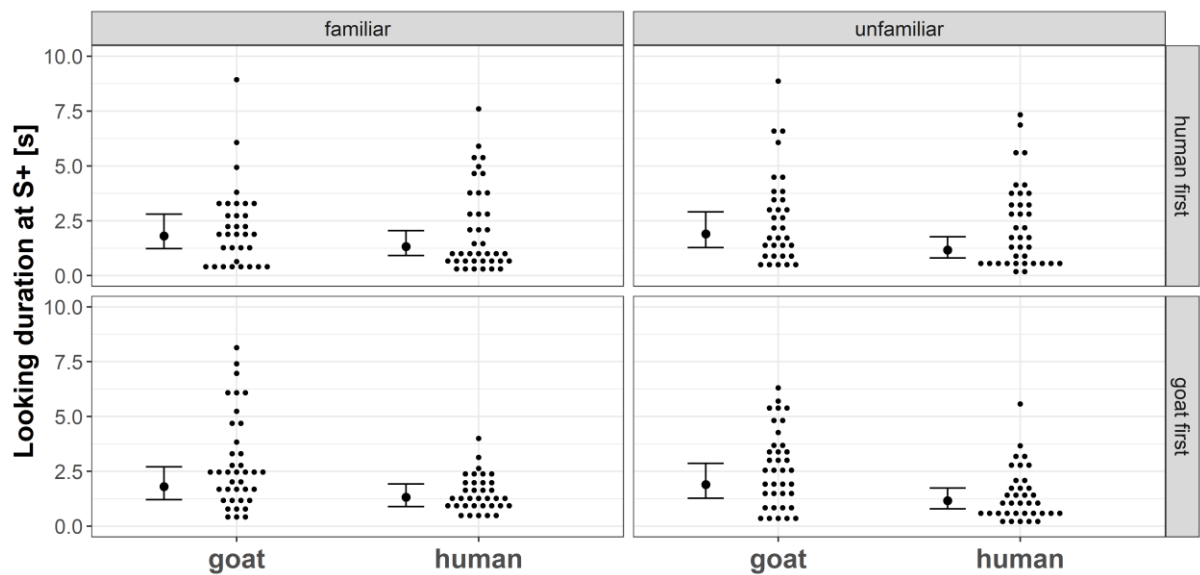
Fig. 6 Small dots represent the looking duration at the video screen presenting a stimulus (S+) across species, familiarity, and testing order. Larger black dots are the corresponding model estimates for each condition, and thin black lines and whiskers are the 95 % confidence intervals of the maximum 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.

17
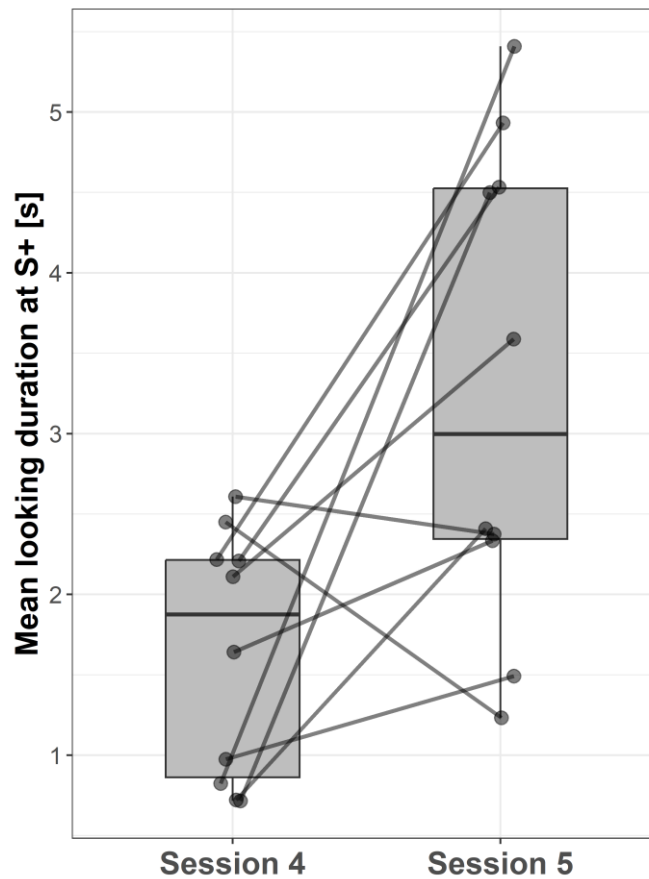
Fig. 7 Boxplots showing the mean looking durations at S+ in sessions 4 and 5 (stimulus switch from human to goat or vice versa) for all subjects. Lines indicate data points from the same individual

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 goats 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 are 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 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 goats 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 an inherent trait or influenced by developmental factors. In our study, limited exposure to humans

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

512 Alternatively, a possible reason for the shorter looking durations at the human
513 stimuli might be due to avoidance of the human face images, as the presented humans
514 might be perceived as possible predators (Davidson et al., 2014). This might have led
515 to behavioural responses aimed at reducing the time the human images can be
516 observed, e.g. by moving away from the experimental apparatus. In sheep, human
517 eye contact altered behaviour compared to no human eye contact, resulting in more
518 locomotor activity and urination when being stared at, but no differences in fear-related
519 behaviours, such as escape attempts (Beausoleil et al., 2006). This might imply that
520 human eye contact can be interpreted as a warning cue for sheep (Beausoleil et al.,
521 2006). Goats, in our study, might thus have simply avoided the human image (and
522 gaze) rather than showing an active preference for goat images.

523 Additional support for H2 is provided by the finding that the subjects in our study

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

539   Contrary to our third prediction (P3), we found no statistical support for
540 differences in the looking behaviour with respect to the familiarity of the depicted
541 individuals. Consequently, we have to reject the hypothesis that goats are able to
542 spontaneously recognise familiar and unfamiliar con- and heterospecifics when being
543 presented with their faces as two-dimensional images (H3). There are several possible
544 reasons, of varying likelihood, that might explain this finding. One possibility is that the
545 subjects were simply not able to differentiate between familiar and unfamiliar
546 individuals because they did not form the concept of familiar or unfamiliar individuals
547 associated with social recognition in general. Alternatively, visual head cues alone
548 might not be sufficient for goats to form these categories. Keil et al. (2012) even found
549 that goats don't necessarily need to see a conspecific's head to discriminate between
550 group members and goats from another social group. In contrast to this, results from
551 other ruminants, such as cattle (Coulon et al., 2011) and sheep (Peirce et al., 2000,
552 2001), have shown that a set of ruminant species have the capability to form this
553 concept using two-dimensional head cues in a visual discrimination task. Langbein et
554 al. (2023) also found some evidence that goats are able to associate two-dimensional
555 representations of conspecifics with real animals in a visual discrimination task. It is
556 therefore surprising to see that the subjects in our study did not show differential
557 looking behaviour with respect to the familiarity of the individuals presented. It might

558 also be possible that subjects were indeed able to differentiate between the categories
559 of stimulus familiarity, but had the same level of motivation (but for different reasons)
560 to pay close attention to both categories, resulting in similar looking durations. The
561 different reasons for looking at either familiar or unfamiliar con- or heterospecifics (e.g.
562 novelty (Fantz, 1964; Tulving & Kroll, 1995), threat perception, individual recognition,
563 positive associations or social buffering (for a more detailed discussion see Rault,
564 2012)) might therefore have compensated for each other and could, ultimately, have
565 led to the absence of a visual preference for a specific category in this study. This
566 assumption also seems plausible when considering the results of Demaria & Thierry
567 (1988), who presented both images of familiar and unfamiliar conspecifics to stump-
568 tailed macaques. They did not find a difference in the looking durations at both stimulus
569 categories but did observe that when looking at the image of a familiar conspecific,
570 some subjects turned back to look at the social group to which the stimulus macaque
571 belonged to. This pattern was never observed for unfamiliar conspecifics, which might
572 indicate that the subjects did indeed distinguish between familiar and unfamiliar
573 individuals. However, this capability could not be inferred from the looking durations
574 at the images *per se* as they also showed no preference for any of the categories.

575 We did not find statistical support for an association between the presented
576 stimulus species or the familiarity of the depicted individuals and the amount of time
577 spent with the ears in a specific position. A higher percentage of the ears in a forward
578 position might be associated with situations that lead to high arousal and/or increased
579 attention in goats (Bellegarde et al., 2017; Briefer et al., 2015). Thus, it seemed
580 probable that the subjects in our study would show a higher percentage of ears in a
581 forward position when being presented with the stimulus species that they looked
582 longer at (here, goat faces). We can only speculate as to why this was not the case in
583 our study. One possibility could be that the "ear forward position", as well as the "ears
584 backward position", is not solely associated with the level of arousal or attention in
585 goats, but also with the valence of the situation experienced by the animal (Bellegarde
586 et al., 2017; Briefer et al., 2015). As we cannot safely infer from our looking duration
587 data that subjects actually perceived the two-dimensional images of the stimulus
588 subjects as representations of their real, three-dimensional counterparts, we cannot
589 make good assumptions about the particular levels of valence and arousal that our
590 stimuli might have elicited in our focal subjects, making a comparison problematic. It
591 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. Assessing the social relationships between the subjects in their home environment, such as dominance rank or the distribution of affiliative interactions, could carry additional information when explaining potential biases or preferences in subjects' looking duration and should be considered in future studies. Finally, a more diverse study population (larger age range, more than one sex tested, etc.) will help to make more generalizable statements about social visual preferences in goats. 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 factors 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, writing – review & editing

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/

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