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Individual Personality Differences in Goats Predict Their Performance in Visual Learning and Non-Associative Cognitive Tasks

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8 **Individual personality differences in goats predict their performance in visual learning**
9 **and non-associative cognitive tasks**

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28 **Highlights**

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- 30 • We investigated goat personality and performance in different cognitive tasks
- 31 • Feature cue preference of goats was also examined
- 32 • Slow explorers performed better in a non-associative cognitive task
- 33 • Less sociable subjects performed better in a visual discrimination task
- 34 • Good visual learning performance was associated with a preference for feature cues

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Abstract

Variation in common personality traits, such as boldness or exploration, is often associated with risk–reward trade–offs and behavioural flexibility. To date, only a few studies have examined the effects of consistent behavioural traits on both learning and cognition. We investigated whether certain personality traits ('exploration' and 'sociability') of individuals were related to cognitive performance, learning flexibility and learning style in a social ungulate species, the goat (*Capra hircus*). We also investigated whether a preference for feature cues rather than impaired learning abilities can explain performance variation in a visual discrimination task. We found that personality scores were consistent across time and context. Less explorative goats performed better in a non-associative cognitive task, in which subjects had to follow the trajectory of a hidden object (i.e. testing their ability for object permanence). We also found that less sociable subjects performed better compared to more sociable goats in a visual discrimination task. Good visual learning performance was associated with a preference for feature cues, indicating personality-dependent learning strategies in goats. Our results suggest that personality traits predict the outcome in visual discrimination and non-associative cognitive tasks in goats and that impaired performance in a visual discrimination tasks does not necessarily imply impaired learning capacities, but rather can be explained by a varying preference for feature cues.

Keywords: cognition; exploration; feature cues; learning type; sociability; transposition

1. Introduction

Personalities refer to consistent individual differences in behaviour across time and context (Réale et al., 2007), and have been demonstrated across many taxa (Briard et al., 2015; David et al., 2011; Morton et al., 2015; Pike et al., 2008; Rodríguez-Prieto et al., 2011). Consistent behavioural responses are traditionally arranged along five key personality axes that include exploration/avoidance, bold/shy, aggression, sociability and activity (Gosling, 2001; Réale et al., 2007). Accumulating evidence suggests that the variation of personality traits observed within populations is heritable and has fitness advantages (Dingemanse et al., 2002; Sih et al., 2004). Personality traits are therefore likely to be under evolutionary selection.

According to selection theory, the maintenance of variation in personality traits within a population results from individual trade-offs between current and future fitness returns (Dall et al., 2004; Wolf et al., 2007). Individuals directing energy towards immediate fitness goals will display risky behaviours, such as boldness toward predators or fast explorers of novel situations (Sih et al., 2004). In contrast, individuals concentrating energy towards future fitness goals will display risk-averse behaviours, displaying shy and non-aggressive behaviours towards other individuals and be slow to explore novel environments.

Consistency in risk prone or risk aversive behaviours within a population (otherwise known as coping strategies) are made up of suites of correlated personality traits (Drent et al., 2003; Verbeek et al., 1996). Correlations between boldness, aggression and exploration have been seen in many taxa and reflect alternatives in life history strategies (Dingemanse et al., 2004; Marchetti and Drent, 2000; Wolf et al., 2007). If correlations between personality traits are components of broader life-history strategies, then it might be expected that individual variation in other behavioural and physiological traits could also be related and exist within populations. It has been suggested that personality trait differences (e.g. bold, fast explorers or shy, slow explorers) may be linked to variation in behavioural flexibility and learning performance via differences in attention to environmental cues and the degree to which internal and external

cues guide behaviour (Carere and Locurto, 2011). For example, in great tits (*Parsus major*), slow explorers respond to external stimuli by readily adjusting their behaviour to changes in their environment, compared to fast explorers that have active routines and do not perform well in fluctuating environments (Verbeek et al., 1996). It could therefore be expected that slow explorers would excel in acquiring information in situations when changes in environmental cues are relevant, such as locations or stimuli associated with food (Guillette et al., 2011). Such differences in internal and external cues for guiding behaviour can then be the link by which personality affects behavioural responsiveness, learning ability and successful adjustment to environmental changes.

The relationship between personality traits and learning ability is also supported by several studies on reversal learning. In reversal learning, animals first learn to discriminate between two stimuli, where one of the stimuli is rewarded. In the reversal phase, the rewarded stimulus is changed; the previously unrewarded stimulus now becomes rewarded, requiring a shift of attention. Fast explorers (or bold and proactive animals) are better at learning an initial discrimination task (Benus et al., 1987; Guillette et al., 2009) but slow explorers (or shy, reactive animals) are better at adapting to changes in an already learned task (Bolhuis et al., 2004; Guillette et al., 2011). However, some studies in birds do not show this relationship between explorative behaviour and behavioural flexibility (Bebus et al., 2016; Cole et al., 2011), while others even show the opposite effect (Bousquet et al., 2015).

Sociability (a key axis of animal personality) is defined by Réale et al. (2007) as an individual's reaction to the presence or absence of conspecifics. Like explorative behaviour, it is also connected to other behavioural traits, particularly in the social domain. For example, juvenile dogs (*Canis familiaris*) that are highly sociable are more likely to adopt an interactive conflict resolution strategy, while those that are less sociable tend to react passively (Riemer et al., 2013). Shy female kangaroos (*Macropus giganteus*) have fewer preferred associates within populations, and also have significantly larger mean foraging group sizes compared to bolder individuals, indicating a link between boldness and sociability of subjects (Best et al., 2015).

Therefore, although exploration and sociability can be interconnected (e.g. Best et al., 2015), little is known how sociability is related to behavioural flexibility and learning performance.

Only a few studies (predominantly on primates) have investigated how consistent behavioural traits, such as boldness or sociability, predict performance in non-associative cognitive tasks. For example, common marmosets (*Callithrix jacchus*) that express higher emotional reactivity show a lower participation rate in a cognitive task in which they had to use human-given cues to find food (Schubiger et al., 2015). However, the level of emotional reactivity did not predict performance in the task. Other research rated capuchin monkeys (*Cebus apella*) on five personality dimensions and analyzed their participation rate and performance in a specific cognitive task (Morton et al., 2013). In this task, a small opaque cup was placed in front of one compartment and a larger opaque cup in front of another compartment. The correct response was to sit in the compartment that had the larger cup in front of it. Individuals that scored high on openness were more likely to participate in the task, whereas less assertive subjects performed better in the task. This negative effect of assertiveness may be best understood as individuals having motivational priorities other than food.

For ungulates, most studies investigating behavioural types and correlates to other behavioural traits focused on coping types (being either proactive or reactive). Pig (*Sus scrofa*) coping types are associated with aggression (Melotti et al., 2011) and also affect exploration patterns but not performance in a maze task (Jansen et al., 2009). In goats, Lyons (1989) found that they express consistent individual differences in temperament, in terms of reaction to humans (timidity), which reliably predict differences in pituitary adrenal responsiveness. Additionally, social strategies in conflict resolution is associated with personality traits in goats (Miranda-de la Lama et al., 2011). Recently, it was shown that personality traits such as exploration/avoidance behaviour and sociability towards other goats are stable over a time interval of about one year. In addition, heart rate responses of the goats were predicted by their sociability outcomes, but not their exploration/avoidance behaviour (Briefer et al., 2015).

We examined whether personality traits predict performance in learning and non-associative cognitive tasks in goats. We first assessed inter-individual differences in exploration behaviour towards novel items and altered environments, and sociability towards other goats by using four different behavioural tests. 'Exploration' scores were obtained using an altered environment and a novel object task (Dingemanse et al., 2007; Lansade et al., 2008a). 'Sociability' was measured using behavioural expressions during the presence and absence of conspecifics (Lansade et al., 2008b). We combined all the correlated behaviours in one score for each personality trait, i.e. exploration and sociability (McGregor, 2013). Goats then participated in three tasks. In a visual discrimination task, we investigated the ability of goats to associate a reward with the colour of a particular container. In a non-associative cognitive task, goats had to track the movement of two containers that crossed paths; a so called transposition task that has previously been successfully tested on goats (Nawroth et al., 2015). Finally, we determined the affinity of goats towards feature cues (such as shape and colour) by providing them with a brief experience of combined feature and spatial cues during a short training period. In the test, feature and spatial cues were incongruent and by analyzing the goats' choices, we could infer their inclination to orient on feature rather than spatial cues. We expected fast explorers to perform better in the visual discrimination task learning (Guenther et al., 2014; Guillette et al., 2009). In addition, we predicted that performance in the visual discrimination task and a non-associative cognitive task would be predicted by the sociability of the test subjects, with higher sociability scores resulting in poorer performance due to differences in motivation rather than on different cognitive skills (Morton et al., 2013). If poor performance in a visual discrimination task was not caused by impaired learning abilities but rather due to a different learning strategy, we expected that better visual learners would show higher affinity for feature cues in the preference task.

2. Materials and methods

2.1. Ethics statement

Animal care and all experimental procedures were in accordance with the ASAB/ABS Guidelines for the Use of Animals in Research (Association for the Study of Animal Behaviour, 2016). The study was approved by the Animal Welfare and Ethical Review Board of Queen Mary University of London. All measurements were non-invasive, and the experiment lasted not more than 10 min for each individual goat. If the goats had become stressed, the test would have been stopped.

2.2. Animals, keeping and management

The study was carried out at Buttercups Sanctuary for Goats (<http://www.buttercups.org.uk>), UK. We tested 16 adult goats (eight females and eight castrated males), which were fully habituated to human presence due to previous research (Baciadonna et al., 2013; Briefer and McElligott, 2013). They were between 2-11 years of age and of various breeds (Table 1). Routine care of the animals was provided by sanctuary employees and volunteers. The goats had ad libitum access to hay and were not food restricted before testing. The experiments were carried out in temporary enclosures, within the normal daytime range of the goats. Subjects were tested from 12:00-16:00h from May to July 2015.

2.3. Personality tests

Two personality traits relevant to social species were measured: Exploration (i.e. reaction to a new situation) and sociability (i.e. reaction to the presence or absence of conspecifics (Réale et al., 2007)). Two separate experiments were conducted per trait to test for consistency across situations. Additionally, each personality test was repeated at two different time points (3 week intervals) to test for consistency over time. Exploration was measured using a novel object test

(Lansade et al., 2008a) and an altered environment test (Dingemanse et al., 2007), both in familiar environments. Sociability was measured using an attraction test in a familiar environment and an isolation test in a less familiar environment (Lansade et al., 2008b). Several behavioural responses were measured from each test (Table A.1 in Appendix). A principal component analysis (PCA) was carried out in order to combine all correlated behaviours into one score, which would be representative of the response of the subjects to the tests (McGregor, 2013). From the resulting PCA (one for each personality trait), we selected the scores of the most relevant principal component (PC), verified score consistency over the three weeks, and averaged the PC scores to obtain one personality score for each goat. The personality tests and methods used to calculate personality scores are detailed in the Appendix, and the resulting scores for 15 goats tested in this study are listed in Table 1. Note that one subject had to be excluded due to a consistent side bias in the tests described below (see results section). Highly positive exploration scores indicated goats that spent more time exploring the novel item or environment. Highly positive sociability scores indicated highly social goats (i.e. reacted strongly to isolation and spent time with other goats during the attraction test; see Appendix).

Table 1 Information on test subjects: ID, breed, sex, age and personality scores (exploration and sociability).

Goat	Breed	Sex	Age in years	Exploration	Sociability
1	Boer	female	2	2.90	2.67
2	Anglo Nubian	female	7	-0.71	1.78
3	Anglo Nubian	male	4	-1.85	0.14
4	Anglo Nubian	male	4	-3.18	-1.44
5	Anglo Nubian	male	6	-1.22	-1.90
6	Mix	female	5	1.94	1.24
7	Mix	male	7	-0.17	-2.25
8	Anglo Nubian	female	10	-0.53	1.29
9	British Saanen	male	7	0.04	-1.31
10	British Alpine	female	11	2.41	-1.41
11	Anglo Nubian	female	9	-3.85	-2.28
12	British Toggenburg	male	5	1.24	0.13
13	British Toggenburg	male	7	0.58	-3.05

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14	Anglo Nubian	male	4	0.69	0.06
15	British Alpine	female	9	-1.81	0.64

2.4 Learning and cognitive tasks

For training and testing in the visual discrimination task and the non-associative cognitive task, individual goats were physically and visually separated from conspecifics in a test pen (2 m x 2.5 m). An experimenter positioned himself in an adjacent compartment separated from the tested subject by grating, allowing subjects to insert their snouts through two openings positioned on either the left or right side of the grating (12 cm x 10 cm). The distance between the openings was 30 cm. A sliding board (58 cm x 30 cm) was placed on a small table (height: 45 cm) in front of the grating (Figure 1a). For the feature preference task, goats were physically and visually separated from conspecifics in a larger test pen (3 x 6 m). Subjects received a habituation trial prior to training and testing to determine whether they displayed any signs of stress during isolation. Half of the subjects received the visual discrimination task first, while the other half received the cognitive task first. The feature preference task was always administered last.

2.4.1 Visual discrimination task

Goats were assigned to an initial training period of four trials in total. In each trial, the experimenter either placed a black or a white cup (diameter: 9 cm; height: 13 cm) at the left or right side of the board and baited it in full view of the subject with a piece of pasta. The subject then had the opportunity to make a choice by putting their snout through one of the outer left or right gaps in the grating and, if chosen correctly, obtained the reward (Figure 1a). In the discrimination task, half of the subjects received a reward by choosing the black cup while the other subjects received a reward by choosing the white cup. Before each test trial, the experimenter baited the corresponding cup surreptitiously. Each different coloured cup was then either placed on the left or right hand side of the sliding board at a distance of about 35 cm. After approximately 2 s, the experimenter pushed the board towards the grating. The subject made its choice by putting its snout through one of the left or right gaps in the grating and if chosen correctly obtained the reward. Subjects were considered to have reached a distinct

learning criterion when they achieved eight correct choices in eight consecutive trials (8/8 would result in $P < 0.008$; binomial test). They received a total number of three sessions, each consisting of 32 trials. Maximum trial number was set at 96 trials (supplementary video).

2.4.2. Non-associative cognitive task

In four training trials prior to testing, the experimenter placed a brown cup (diameter: 9 cm; height: 11 cm) on either the left or right hand side of the board. The cup was baited in full view of the subject with a small reward (a piece of dry pasta). Immediately afterwards, the experimenter pushed the board towards the grating and the subject was allowed to make a choice by placing its snout through the appropriate gap. In test trials, subjects were presented with a transposition in which two identical brown cups crossed paths and their positions switched. Two cups were placed on the left and the right side of the sliding board and a food reward was placed in one of the cups in full view of the subject. After baiting, the experimenter simultaneously moved the left cup to the right side, and the right cup to the left side of the board, so that the cups crossed path in the middle. The baited cup crossed path in the direction of the test subject in 50% of the trials. After the transposition, the experimenter immediately pushed the sliding board towards the grating, allowing the subjects to make a choice. Each subject received only one test session of 12 trials (supplementary video).

2.4.3. Feature preference task

The feature preference task was conducted one week after subjects participated in the visual discrimination task and the cognitive task. Two different types of containers were used: a square brown container (length: 16 cm, height: 18 cm) and a round black container (diameter: 14 cm, height: 9 cm). In all trials, three containers were positioned in total in the test area. In training trials, either one rewarded round black container, or one rewarded square brown container was positioned at the left or right side of a semicircle, respectively. Two additional containers of the other respective type were positioned in the middle and on the opposite side of

the semicircle (see Figure 1b) but remained unrewarded. The containers were arranged in a semicircle so that each container had the same distance towards the starting point of the goat (250 cm). The distance between containers was 50 cm. Each subject received three training trials. In these trials, an experimenter baited either the left or right container (either the single square brown container or the single round black container) in full view of the subject whilst they approached the experimenter. In all trials, the subject moved directly towards the baited location. After training, subjects proceeded to the preference trials. During the preference test, all containers were baited with a food reward and the position of the former rewarded container was changed from the right to left position or vice versa, depending on the former experienced location. After a trial had finished, the experimenter re-baited the container chosen by the goat and sham-baited the other two containers. Each subject received 10 successive preference trials. Seven subjects started with the rewarded container positioned on the left side, while 8 subjects started with the rewarded container on the right side. For eight subjects, the rewarded container was the square brown container, for seven subjects it was the round black container.

Figure 1 Setup of the experiments: a) visual discrimination task (similar to the non-associative cognitive task) b) feature preference task

2.5 Data scoring and analysis

All trials were scored live during the test and were also videotaped (Sony HCR-CX190E Camcorder). A test trial ended after a goat made a choice or after 60 s had passed. For the visual discrimination (N = 12) and the cognitive task (N = 15), we scored the correct choices of all subjects. For the visual discrimination task, we ranked subjects based on the number of trials

they needed to reach the learning criteria (lower rank numbers indicate faster learning) as trials were skewed towards the minimum (8) and the maximum amount of trial (96 trials) needed. In the feature preference task (N = 15), we scored the total number of feature choices of subjects. A feature choice was defined as choosing the previously rewarded container (square brown or round black container) in a new spatial configuration. One subject had to be excluded from the analysis, because it consistently showed a side bias in all tasks. In the visual discrimination task, two subjects had to be excluded as they lost interest in the task quickly, and an additional subject was excluded because it was interfering with the grating. We used a linear regression model with step-wise elimination of non-significant parameters to determine whether the outcomes of the different tasks were predicted by their personality scores (exploration and sociability), including sex, age and breed as covariates. We then used Spearman rank correlations with a Bonferroni adjustment of the alpha level ($\alpha = 0.017$) to compare performances pairwise between the visual discrimination, cognitive, and feature preference task. All analyses were conducted in SPSS v 22.0. α was set at 0.05, unless specified otherwise.

3. Results

Subjects' sociability scores predicted their ranked learning performance, with less sociable subjects requiring fewer trials to reach the criterion ($R^2 = 0.337$, $F_{1,11} = 5.09$, $P = 0.048$, Figure 2). Sociability scores also predicted the number of feature choices made by individuals in the feature preference task, with less sociable subjects choosing the feature container more often compared to more sociable ones ($R^2 = 0.418$, $F_{1,11} = 5.09$, $P = 0.009$). Exploration scores predicted the performance in the cognitive task, with low explorative subjects performing better compared to highly explorative goats ($R^2 = 0.268$, $F_{1,14} = 4.758$, $P = 0.048$; Figure 2). Sex, age and breed had no significant effects on task outcomes. Finally, we calculated correlations between the performances of subjects in all three tasks. Good performance in the visual discrimination task was highly correlated with preference for feature cues ($r = -.608$, $N = 12$, $P =$

0.009). No other significant correlations were found (Visual discrimination task x cognitive task: $r = -.016$, $N = 12$, $P = 0.94$; feature preference task x cognitive task: $r = 0.087$, $N = 15$, $P = 0.68$).

Figure 2 Relationship between the ranked performance in the visual discrimination task and the PCA score for sociability (left) and the performance in the cognitive task and the PCA score for exploration (right); the dashed line indicates performance by chance level

4. Discussion

We investigated how personality types in goats predicted the outcomes of various cognitive tasks. Personality scores of individual subjects were repeatable over a short time period (3 weeks) and thus confirm previous findings (Briefer et al., 2015). Less explorative goats performed better in a non-associative cognitive task, in which subjects had to follow the trajectory of a hidden object. Performance in a visual discrimination task was related to their sociability scores, with less sociable subjects outperforming more sociable ones. In addition, the preference of subjects to relocate food patches using feature or other cues (as displayed in the feature preference task) was predicted by personality scores. A high preference for feature cues was associated with low sociability scores and good performance in the visual discrimination task. Our results suggest that the personality profile of goats is related to their performance in various cognitive tasks (Guillette et al., 2009; Morton et al., 2013).

We found that exploration scores of subjects predicted their performance in a transposition task. In this task, subjects had to keep track of a hidden object while two possible baiting containers had their positions swapped. It is possible that even a short moment of distraction can lead to errors, because subjects may mistake the baited container with the empty one due to their identical appearance. Indeed, it has been shown that using two differently coloured and shaped boxes slightly improved performance in the task in goats (Nawroth et al., 2015). Thus, the good performance of less explorative goats in this transposition task may be explained by their potentially decreased arousal by additional external cues, leading to a higher inclination to pay attention to the task. Alternatively, it has been suggested that slow explorers are expected to perform better when changes in environmental cues are relevant, such as changes in locations or stimuli associated with food (Guillette et al., 2011, 2009). To date, only a few studies have investigated how personality traits predict outcomes and participation rate in non-associative cognitive tasks. Participation rate of common marmosets in an object choice task was related to their emotional reactivity (Schubiger et al., 2015), while capuchin monkeys with higher openness scores were more inclined to participate in a choice task (Morton et al., 2013). In light

of these findings, our results may be best understood as highly explorative individuals having motivational priorities other than food rather than cognitive impairments. Controversially, there was no connection between goats' performance in a discrimination task and their exploration scores.

Previous research has found a correlation between learning performance and explorative behaviour (Guillette et al., 2011, 2009). Contrary to expectations, we did not find a similar effect. However, previous research has also shown mixed results. For example, when presented with a visual discrimination task and a reversal learning task, explorative behaviour was not linked to performance in Florida scrub-jays (*Aphelocoma coerulescens*) (Bebus et al., 2016). Performance in a visual discrimination task in our experiment was associated with sociability scores of our subjects, with less sociable subjects outperforming more sociable ones. More social subjects might be more stressed while tested individually, leading to distraction and poorer performance. This, in turn, may have resulted in decreased attention towards the task and longer time to reach the learning criterion. If this was the case, we might expect a similar effect for the non-associative cognitive task, but the performance in that task was not related to their sociability scores.

Interestingly, sociability was associated with a higher inclination to choose feature cues in a preference task. These results tend to point in the direction that sociability, or a certain personality type in general, can be linked to learning style, i.e. paying more attention to feature or spatial cues. This means that impaired learning capacities do not necessarily have to be the exclusive reason for poor performance in a visual discrimination task. In addition, other factors such as stress or arousal may contribute to a decline in performance, different preferences for learning of either feature and/or spatial cues have to be taken into account. Because memorizing food patches is essential when making foraging decisions, different strategies to achieve this goal are available. For example, subjects can relocate food patches by memorizing feature cues such as size and colour, or by spatially representing the environment, using local or global landmarks (Shettleworth, 2010). Using feature cues such as colour or shape to identify

food patches can increase foraging efficiency. However, feature cues may change over time and therefore animals should use spatial cues to relocate food that occurs in a temporally stable position. For example, European greenfinch (*Carduelis chloris*) show context-dependent preferences in that they are able to learn feature and spatial cue types, while spatial cues are favoured over feature cues only in temporally stable contexts (Herborn et al., 2011). Some subjects may develop a preference for one cue type over the other due to different ontogenetic factors and individual experience.

Ungulates have been shown to possess personality traits that are stable over time (Briefer et al., 2015; Graunke et al., 2013). Previous research in goats has linked these traits to hormonal (pituitary adrenal responsiveness: Lyons, 1989) and physiological parameters (heart rate response: Briefer et al., 2015). To our knowledge, our results show first evidence for a link between certain personality traits and discrimination learning and cognitive performance in goats. In pigs, their coping types affected motivation and exploration, but not performance in an initial maze task (Jansen et al., 2009). By contrast, proactive pigs have been found to be less successful in a reversal learning task than reactive pigs (Bolhuis et al., 2004). This is in line with research on other species (Guillette et al., 2009) and suggests that proactive (i.e. more explorative) pigs have a higher propensity to develop inflexible behaviour.

We conclude that different personality traits predict the outcome in visual discrimination and non-associative cognitive tasks in goats. In addition, we found that an impaired performance in a visual discrimination tasks does not necessarily imply an impairment of learning in general, but rather can be explained due to different preferences towards feature or spatial cues. The particular link between sociability and its association with learning performance and preferences for particular cue types seems to be a promising area for future research and needs to be taken under consideration when discussing potential impairments in learning capacities in future research in other ungulate species. These findings will lead to advances in animal welfare in the long term by providing important insights into individual differences in personality traits in livestock and how they are related to behavioural outcomes in different contexts.

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566

Appendix

Experimental Procedure of Personality Tests

We assessed exploration (i.e. reaction to a new situations, Réale et al., 2007) using a novel object test (Lansade et al., 2008a) and an altered environment test (Dingemanse et al., 2007), both in familiar environments. Sociability was measured using an attraction test in a familiar environment and an isolation test in a less familiar environment (Lansade et al., 2008b). Tests were conducted during May 2015 and repeated in June 2015. Several behavioural responses were measured from each test (Table A.1).

The novel object, altered environment and attraction tests were carried out in a familiar stable complex in a 4.5 m by 3 m pen (A), inside the main building of the sanctuary. Pen A was split into quadrants Q1 to Q6 each 1.5 m x 1.5 m in size (Figure A.1). Because goats were not able to leave the pen during each test, the start quadrant (situated next to the pen gate and away from the test area) was provided as a refuge so that goats could retreat from the test if necessary, in addition to avoiding measuring behaviours unrelated to the exploration personality trait, such as fear and anxiety (Carter et al., 2013; Näslund et al., 2015).

The isolation test was carried out in a separate pen, which was 2 m by 2 m. The isolation pen was a familiar area, but the subjects were not habituated to it in order to measure behaviours associated with separation anxiety (Réale et al., 2007). This pen was situated at the back of the building to reduce additional stress caused by external factors such as noise or movement.

Goats were habituated to Pen A over 3 days, for 10 min each day (total: 3 days for 16 goats), during which access to hay and water was given *ad libitum*. All goats had access to all pens and outbuildings at the study site throughout the day. However it was necessary to habituate each goat so that they became accustomed to being handled (Walf and Frye, 2007). In addition,

595 habituation of goats within Pen A was necessary to reduce anxiety and stress caused by
596 isolation (Cohen and Wills, 1985).

597
598 Individual goats entered the pens through the gate, after which the behaviour of each focal
599 individual was recorded for 5 min with a video camera (Sony HDR-CX190). Recordings started
600 from the point that the experimenter closed the pen gate. After the 5-minute period, the pen
601 gate was opened and the focal goat was free to leave the test pen. Each individual test was
602 carried out on the same day, and repeated 3 weeks after the initial test had taken place using
603 the same methodology. The order in which goats were tested was random on each test day,
604 and for each Repeat.

Figure A1. Test setups for the a) novel object test b) and c) altered environment test d) attraction test

Exploration

The novel object test was carried out in Pen A with a novel item, which was placed on the floor in the middle of quadrant 3 and 4 (Figure A.1a). In the first Repeat, the novel object was an inflatable child's toy that was 40 cm high and 30 cm in length. The second Repeat used a large multi-coloured beach ball that was 40 cm high. The altered environment test was also carried out inside Pen A. The layout of the pen was altered from the normal layout to which goats were habituated to in the habituation phase. Gates were used to create an altered environment in two different layouts in the first and second Repeat of this test (Figure A.1b-c).

Sociability

The attraction test was carried out in Pen A, with the pen mate of the focal goat housed in an adjacent pen B, where focal goats could easily view and touch pen mates (Figure A.1d). Once the pen mate was housed inside the adjacent pen, the focal goat then entered Pen A through the gate by the start quadrant after which recording of the focal goat began. The isolation test was carried out in a separate pen. Individual goats entered the pen and the gate was closed behind them. The behaviour of each individual goat was recorded, starting from the point that the experimenter left the area and was out of sight of the focal goat. After the 5-min test period, the focal goat was released and free to leave the test pen.

Table A1. Ethogram showing descriptions of behaviours scored during personality tests.

Adapted from Briefer et al. (2015).

Trait	Test	Behaviour	Description
Exploration/ Avoidance	Novel Object	Time Interact	Time spent interacting with the object (i.e. touching with any body part, or smelling with muzzle at 1-10 cm from the object)
		Latency Interact Object	Latency to touch or smell the object (i.e. touching with any body part or smelling with muzzle at 1-10 cm from the object) *
		Time in Object Proximity	Time spent within 50 cm radius of object**
		Time Start Quadrant	Time spent in start area quadrant**
		Time Perimeter	Time spent within 50cm from perimeter walls of pen (excluding start quadrant)**
	Altered Environment	Latency to Explore	Latency to touch or smell a surface of the pen (touching with any body part, or smelling with muzzle at 1-10 cm from any surface) *
		Time Mobile Explore	Time spent touching or smelling a surface of the pen (touching with any body part, or smelling with muzzle at 1-10 cm from any surface) whilst moving around pen - defined as locomotion behaviour
		Time Immobile Explore	Time spent touching or smelling a surface of the pen (touching with any body part, or smelling with muzzle at 1-10 cm from any surface) whilst remaining immobile
		Time Start Quadrant	Time spent in start area quadrant**
		Time Quadrant 1-6	Time spent in quadrants 1-6**
		Quadrant Frequency	Frequency of quadrant changes
		Locomotion	Time spent moving around pen - defined as movement with a minimum of 3 legs
		Time Standing	Time spent immobile and inactive
	Attraction	Time Companion Proximity	Time spent within 1.5 metres proximity of companion with more than half of body within this distance
		Latency to Companion	Latency to reach 1 metre distance from companion*
		Calls	Call rate per 300s
		Time Contact Companion	Time spent making physical contact with companion with any body part
		Locomotion	Time spent moving around pen - defined as movement with a minimum of 3 legs
		Transitional Behaviour	Number of times change in behaviour e.g.. Walk/stop/move head/walk
		Latency Feed	Latency to start feeding the hay in the feeder or using salt lick*
		Time Feed	Time spent feeding from the feeder or salt lick
		Locomotion	Time spent moving around pen - defined as movement with a minimum of 3 legs
		Time Lying or Kneeling	Time spent lying or kneeling down on 2 legs or more
Sociability	Isolation	Transitional Behaviour	Number of times change in behaviour e.g.. Walk/stop/move head/walk
		Calls	Call rate per 300s
		Time Lying or Kneeling	Time spent lying or kneeling down on 2 legs or more
		Locomotion	Time spent moving around pen - defined as movement with a minimum of 3 legs
		Time Feed	Time spent feeding from the feeder or salt lick
	Attraction	Latency to Companion	Latency to reach 1 metre distance from companion*
		Calls	Call rate per 300s
		Time Contact Companion	Time spent making physical contact with companion with any body part
		Locomotion	Time spent moving around pen - defined as movement with a minimum of 3 legs
		Time Companion Proximity	Time spent within 1.5 metres proximity of companion with more than half of body within this distance

* if this behaviour is not performed, a latency of 300s (total test duration of 5 minutes) will be attributed

** only applicable when more than half of body is in area

Data scoring and analysis

Behaviours recorded during each test were scored using CowLog 2.0 (Hänninen and Pastell, 2009). A template outlining each quadrant, in addition to proximities from pen walls, novel objects and pen mates, was placed over the computer screen when viewing videos for consistency of scoring proximity measures. Table A.1 shows the ethogram used for each personality test, and outlines all behaviours recorded along with their descriptions.

A principal component analysis (PCA) was carried out in order to combine all behavioural parameters in one score for each personality trait, which would be representative of the response of individuals to the personality tests (McGregor, 2013). All the behavioural data taken during the novel object and altered environment tests from the first Repeat were included together in one PCA. A second PCA was calculated using the data collected from the second Repeat. This resulted in two PCA results, one each for Repeat 1 and 2 for the exploration trait. This process was then repeated using the behavioural data taken during the isolation and attraction tests and resulted in a further two PCA results, one for each Repeat 1 and 2 for the sociability trait.

The PCA output provided the loadings of each behaviour on each principal component. The loadings reflect the weight of each behaviour within the component. Only loadings of ≤ -0.3 or ≥ 0.3 were used for reliable PC interpretation (Comrey and Lee, 2013) in addition to eigenvalues ≥ 1.0 for each principle component (Zwick and Velicer, 1986). The first four PCs from the PCA analysis for exploration and the first five PCs for sociability were used in the final analysis as these PC's had eigenvalues ≥ 1.0 .

Loadings from PC1 for both exploration and sociability values were representative of each trait and were therefore used to calculate personality scores for each trait. The data from PC1 for Repeat 1 and 2 of each personality traits was tested for normality using an Anderson Darling test (Exploration (Repeat 1), AD = 0.25, n = 16 goats, $P = 0.72$; (Repeat 2) AD = 0.34, n = 16

goats, $P = 0.46$; Sociability (Repeat 1), $AD = 0.33$, $n = 16$ goats, $P = 0.46$; (Repeat 2) $AD = 0.49$
 $n = 16$ goats, $P = 0.19$). As all data was normally distributed, parametric correlations were
calculated to check for consistency between the repeats of each personality traits. (Pearson's
Correlation: Exploration $r_p = 0.826$, $n = 16$ goats, $P < 0.001$; Sociability $r_p = 0.83$, $n = 16$ goats, P
 < 0.001). Values were consistent between repeats for both exploration and sociability. Means of
Repeat 1 and 2 for each personality trait were then calculated to obtain personality scores for
each individual goat. All statistical analyses were performed using Minitab (Release 13.1 ©
2000 Minitab Inc.).

Results

The output from the PCA performed on the exploration data for Repeat 1 and 2 revealed 4 PCs
with an eigenvalue greater than 1 (Table A.2). These 4 PCs for Repeat 1 and 2 explained 81.0
% and 82.6% of the variance respectively. According to the loadings of the behaviours on the
PCs (Table A.2), the first PC (PC1) reflected exploration behaviour well across both tests for
each Repeat (novel object and altered environment; i.e. goats that were highly explorative in
both tests). The following behaviours were correlated with the first PC for both Repeats
(loadings ≤ -0.3 or ≥ 0.3): time spent immobile exploring (for altered environment), time spent in
start quadrant and frequency of quadrant entered (Table A.2). Highly positive PC1 values
indicated goats that were explorative and spent time investigating the novel object or altered
environment. Highly negative PC1 values indicated goats that did not investigate the novel
object or environment (i.e. spent the majority of time in the start area or at the perimeter of the
pen). The duration of exploring the novel object or environment was shorter in these goats,
compared to subjects with higher exploration scores. These goats did not explore the object or
altered environment at all.

The output from the PCA performed on the sociability data for Repeat 1 and 2 revealed 5 PCs
with an eigenvalue greater than 1 (Table A.2). These 5 PCs explained 83.0% and 80.9% of the
variance respectively, for each Repeat 1 and 2. According to the loadings of the behaviours on

the PCs (Table A.2), the first PC (PC1) reflected sociability well across both tests for each Repeat (attraction and isolation; i.e. goats that were showing increased social responses in both tests, spending time touching companions during the attraction test and reacting strongly to isolation). The following behaviours were correlated with the first PC for both Repeats (loadings ≤ -0.3 or ≥ 0.3): time contact companion (for attraction test), transitional behaviour (for both isolation and attraction tests) and call frequency (for attraction test). Highly positive PC1 values indicated goats that were sociable and spent time in contact with companions. Goats with a high sociability score exhibited a reduction in time spent feeding (or did not feed at all), had higher rates of locomotion within the pen and an increased call frequency during the isolation test, compared to goats with lower sociability scores (Table A.2).

704 **Table A2.** Factor loadings of the measured behavioural parameters for the principal components for test on exploration and sociability (Repeat 1 and
705 Repeat 2). Only principle components with eigenvalues greater than 1 are shown. Only loadings of ≤ -0.3 or ≥ 0.3 (marked in bold) are used for PC
706 interpretation.

Trait	Test	Behaviour	PC1	PC2	PC3	PC4	PC5	PC1	PC2	PC3	PC4	PC5
Exploration	Novel Object	Time Interact	0.222	0.01	-0.543	-0.134		0.32	0.185	0.035	-0.291	
		Latency Interact Object	-0.221	-0.332	0.116	0.095		-0.136	-0.11	0.46	0.357	
		Time in Object Proximity	0.239	0.167	-0.439	0.057		0.288	-0.106	-0.332	-0.076	
		Time Start Quadrant	-0.303	-0.354	-0.005	0.373		-0.257	0.4	0.276	0.232	
		Time Perimetre	0.163	0.295	0.366	-0.45		0.059	-0.528	-0.035	-0.288	
	Altered Environment	Latency to Explore	-0.308	0.16	-0.171	-0.451		0.27	0.331	-0.053	0.032	
		Time Mobile Explore	0.278	-0.205	-0.252	0.075		0.343	0.271	-0.014	0.199	
		Time Immobile Explore	0.314	-0.394	-0.116	-0.057		-0.379	0.172	0.049	-0.253	
		Time Start Quadrant	-0.366	-0.144	-0.291	-0.298		0.379	-0.172	-0.049	0.253	
		Time Quadrant 1-6	0.366	0.144	0.291	0.298		0.021	-0.44	0.43	0.021	
		Quadrant Frequency	0.357	-0.068	0.033	-0.217		0.338	-0.114	0.291	0.336	
		Locomotion	0.014	-0.392	0.29	-0.375		-0.341	-0.219	-0.309	0.197	
		Time Standing	-0.244	0.477	-0.063	0.222		0.133	0.082	0.476	-0.569	
	Eigenvalue		4.3209	2.8317	2.1453	1.2324		5.4373	2.2518	1.7786	1.273	
	Cum % variance		33.2	55	71.5	81		41.8	59.1	72.8	82.6	
Sociability	Attraction	Time Companion Proximity	-0.033	0.321	0.431	0.257	0.224	0.22	0.053	-0.219	-0.089	0.682
		Latency to Companion	0.078	-0.27	-0.08	-0.275	-0.599	-0.212	-0.418	0.164	0.014	-0.421
		Calls	0.027	0.443	-0.406	-0.177	-0.008	0.343	0.036	0.229	0.219	-0.209
		Time Contact Companion	0.349	-0.301	-0.106	0.041	0.013	0.326	-0.053	0.241	0.031	0.158
		Locomotion	0.097	0.511	0.061	0.267	-0.209	0.228	0.417	0.015	0.223	-0.147
		Transitional Behaviour	0.351	0.179	-0.064	0.172	-0.32	0.35	0.118	0.106	0.289	-0.086
	Isolation	Latency Feed	0.203	0.08	0.453	-0.385	0.006	0.207	0.068	-0.371	-0.147	-0.356
		Time Feed	-0.172	-0.072	-0.488	0.101	0.44	-0.226	-0.207	0.371	0.025	0.108
		Locomotion	0.127	0.433	-0.261	-0.319	-0.057	0.19	0.315	0.128	-0.542	-0.204
		Time Lying or Kneeling	-0.188	-0.063	-0.192	0.458	-0.404	-0.049	0.094	-0.398	0.514	-0.105
		Transitional Behaviour	0.324	-0.02	-0.241	-0.232	0.142	0.328	-0.058	0.094	-0.352	-0.145
		Calls	0.362	-0.129	0.056	-0.062	0.205	0.276	-0.28	0.164	0.033	0.196
	Eigenvalue		5.0437	2.6637	1.9349	1.7387	1.1301	5.9695	1.9717	1.8558	1.2615	1.0773
	Cum % variance		33.6	51.4	64.3	75.9	83.4	39.8	52.9	65.3	73.7	80.9

707