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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**

10

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28 **Highlights**

29

- 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

35

36

37 **Abstract**

38

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

56

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

58 **1. Introduction**

59

60 Personalities refer to consistent individual differences in behaviour across time and context
61 (Réale et al., 2007), and have been demonstrated across many taxa (Briard et al., 2015; David
62 et al., 2011; Morton et al., 2015; Pike et al., 2008; Rodríguez-Prieto et al., 2011). Consistent
63 behavioural responses are traditionally arranged along five key personality axes that include
64 exploration/avoidance, bold/shy, aggression, sociability and activity (Gosling, 2001; Réale et al.,
65 2007). Accumulating evidence suggests that the variation of personality traits observed within
66 populations is heritable and has fitness advantages (Dingemanse et al., 2002; Sih et al., 2004).
67 Personality traits are therefore likely to be under evolutionary selection.

68

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

76

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

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

96

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

107

108 Sociability (a key axis of animal personality) is defined by Réale et al. (2007) as an individual's
109 reaction to the presence or absence of conspecifics. Like explorative behaviour, it is also
110 connected to other behavioural traits, particularly in the social domain. For example, juvenile
111 dogs (*Canis familiaris*) that are highly sociable are more likely to adopt an interactive conflict
112 resolution strategy, while those that are less sociable tend to react passively (Riemer et al.,
113 2013). Shy female kangaroos (*Macropus giganteus*) have fewer preferred associates within
114 populations, and also have significantly larger mean foraging group sizes compared to bolder
115 individuals, indicating a link between boldness and sociability of subjects (Best et al., 2015).

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

118

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

132

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

144

145 We examined whether personality traits predict performance in learning and non-associative
146 cognitive tasks in goats. We first assessed inter-individual differences in exploration behaviour
147 towards novel items and altered environments, and sociability towards other goats by using four
148 different behavioural tests. 'Exploration' scores were obtained using an altered environment and
149 a novel object task (Dingemanse et al., 2007; Lansade et al., 2008a). 'Sociability' was
150 measured using behavioural expressions during the presence and absence of conspecifics
151 (Lansade et al., 2008b). We combined all the correlated behaviours in one score for each
152 personality trait, i.e. exploration and sociability (McGregor, 2013). Goats then participated in
153 three tasks. In a visual discrimination task, we investigated the ability of goats to associate a
154 reward with the colour of a particular container. In a non-associative cognitive task, goats had to
155 track the movement of two containers that crossed paths; a so called transposition task that has
156 previously been successfully tested on goats (Nawroth et al., 2015). Finally, we determined the
157 affinity of goats towards feature cues (such as shape and colour) by providing them with a brief
158 experience of combined feature and spatial cues during a short training period. In the test,
159 feature and spatial cues were incongruent and by analyzing the goats' choices, we could infer
160 their inclination to orient on feature rather than spatial cues. We expected fast explorers to
161 perform better in the visual discrimination task learning (Guenther et al., 2014; Guillette et al.,
162 2009). In addition, we predicted that performance in the visual discrimination task and a non-
163 associative cognitive task would be predicted by the sociability of the test subjects, with higher
164 sociability scores resulting in poorer performance due to differences in motivation rather than on
165 different cognitive skills (Morton et al., 2013). If poor performance in a visual discrimination task
166 was not caused by impaired learning abilities but rather due to a different learning strategy, we
167 expected that better visual learners would show higher affinity for feature cues in the preference
168 task.

169 **2. Materials and methods**

170

171 *2.1. Ethics statement*

172

173 Animal care and all experimental procedures were in accordance with the ASAB/ABS
174 Guidelines for the Use of Animals in Research (Association for the Study of Animal Behaviour,
175 2016). The study was approved by the Animal Welfare and Ethical Review Board of Queen
176 Mary University of London. All measurements were non-invasive, and the experiment lasted not
177 more than 10 min for each individual goat. If the goats had become stressed, the test would
178 have been stopped.

179

180 *2.2. Animals, keeping and management*

181

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

190

191 *2.3. Personality tests*

192

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

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

214

215 **Table 1** Information on test subjects: ID, breed, sex, age and personality scores (exploration
 216 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

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

217

218

219 *2.4 Learning and cognitive tasks*

220

221 For training and testing in the visual discrimination task and the non-associative cognitive task,
222 individual goats were physically and visually separated from conspecifics in a test pen (2 m x
223 2.5 m). An experimenter positioned himself in an adjacent compartment separated from the
224 tested subject by grating, allowing subjects to insert their snouts through two openings
225 positioned on either the left or right side of the grating (12 cm x 10 cm). The distance between
226 the openings was 30 cm. A sliding board (58 cm x 30 cm) was placed on a small table (height:
227 45 cm) in front of the grating (Figure 1a). For the feature preference task, goats were physically
228 and visually separated from conspecifics in a larger test pen (3 x 6 m). Subjects received a
229 habituation trial prior to training and testing to determine whether they displayed any signs of
230 stress during isolation. Half of the subjects received the visual discrimination task first, while the
231 other half received the cognitive task first. The feature preference task was always administered
232 last.

233

234 *2.4.1 Visual discrimination task*

235

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

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

251

252 *2.4.2. Non-associative cognitive task*

253

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

267

268 *2.4.3. Feature preference task*

269

270 The feature preference task was conducted one week after subjects participated in the visual
271 discrimination task and the cognitive task. Two different types of containers were used: a
272 square brown container (length: 16 cm, height: 18 cm) and a round black container (diameter:
273 14 cm, height: 9 cm). In all trials, three containers were positioned in total in the test area. In
274 training trials, either one rewarded round black container, or one rewarded square brown
275 container was positioned at the left or right side of a semicircle, respectively. Two additional
276 containers of the other respective type were positioned in the middle and on the opposite side of

277 the semicircle (see Figure 1b) but remained unrewarded. The containers were arranged in a
278 semicircle so that each container had the same distance towards the starting point of the goat
279 (250 cm). The distance between containers was 50 cm. Each subject received three training
280 trials. In these trials, an experimenter baited either the left or right container (either the single
281 square brown container or the single round black container) in full view of the subject whilst they
282 approached the experimenter. In all trials, the subject moved directly towards the baited
283 location. After training, subjects proceeded to the preference trials. During the preference test,
284 all containers were baited with a food reward and the position of the former rewarded container
285 was changed from the right to left position or vice versa, depending on the former experienced
286 location. After a trial had finished, the experimenter re-baited the container chosen by the goat
287 and sham-baited the other two containers. Each subject received 10 successive preference
288 trials. Seven subjects started with the rewarded container positioned on the left side, while 8
289 subjects started with the rewarded container on the right side. For eight subjects, the rewarded
290 container was the square brown container, for seven subjects it was the round black container.
291



292

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

295

296 *2.5 Data scoring and analysis*

297

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

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

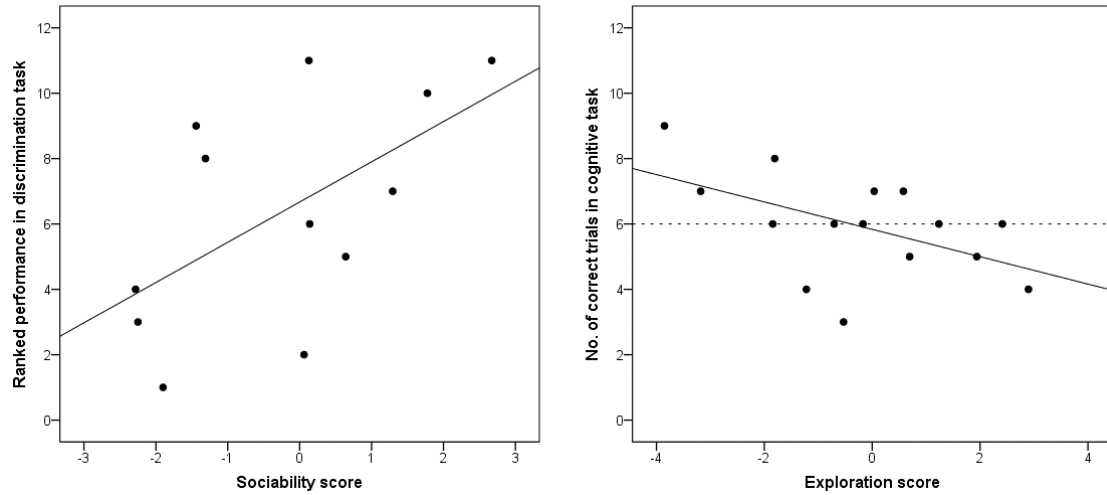
317

318 **3. Results**

319

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

330 0.009). No other significant correlations were found (Visual discrimination task x cognitive task: r
331 = -0.016 , $N = 12$, $P = 0.94$; feature preference task x cognitive task: $r = 0.087$, $N = 15$, $P = 0.68$).
332



333
334 **Figure 2** Relationship between the ranked performance in the visual discrimination task and the
335 PCA score for sociability (left) and the performance in the cognitive task and the PCA score for
336 exploration (right); the dashed line indicates performance by chance level
337

338 **4. Discussion**

339

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

351

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

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

371

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

384

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

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

403

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

414

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

425

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427

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432

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434

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566

567 **Appendix**

568

569 *Experimental Procedure of Personality Tests*

570

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

577

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

585

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

590

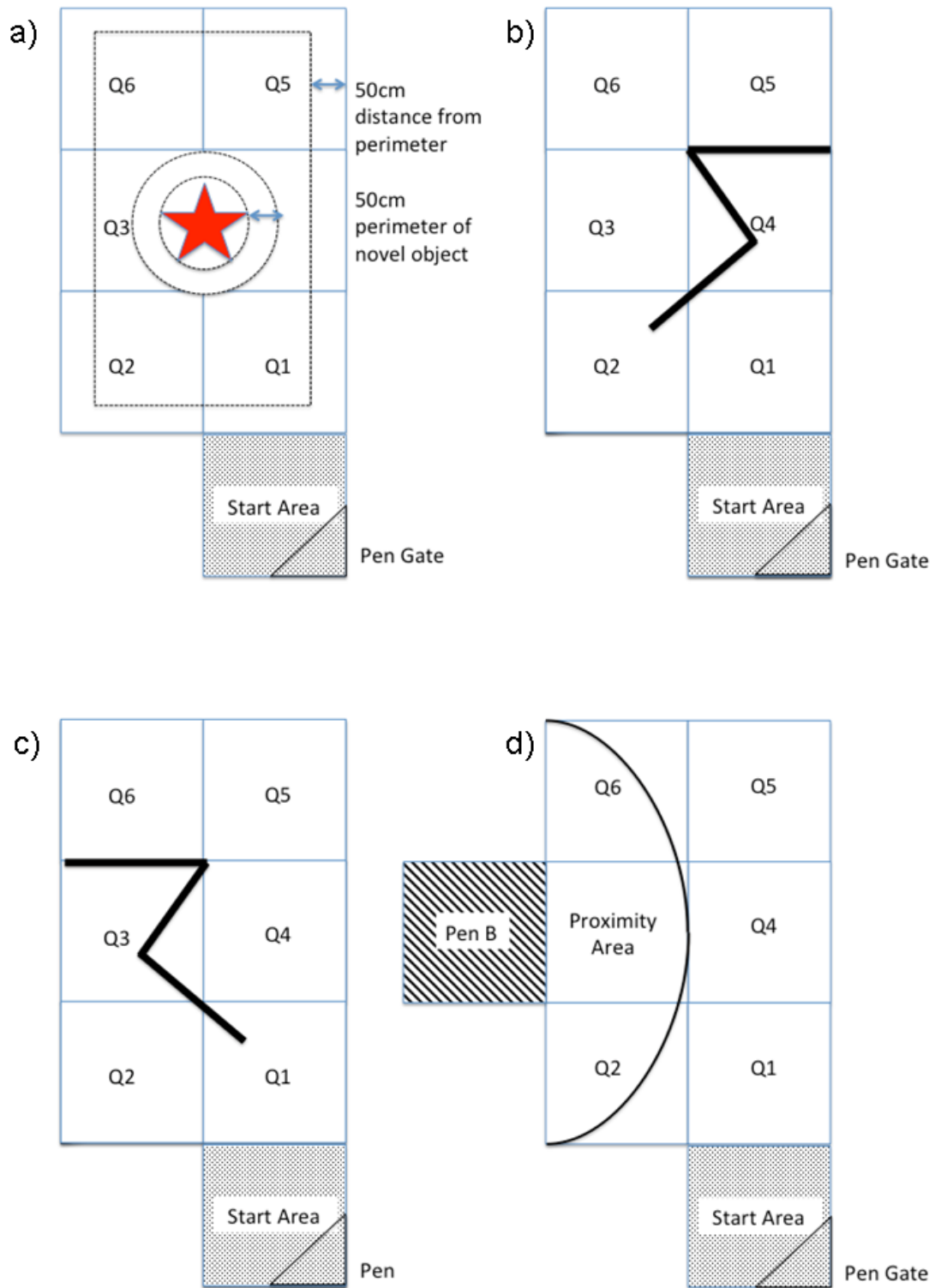
591 Goats were habituated to Pen A over 3 days, for 10 min each day (total: 3 days for 16 goats),
592 during which access to hay and water was given *ad libitum*. All goats had access to all pens and
593 outbuildings at the study site throughout the day. However it was necessary to habituate each
594 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.

605



606

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

608 attraction test

609

610 Exploration

611

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

619

620 Sociability

621

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

630

631

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

633 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
		Sociability	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		
Transitional Behaviour	Number of times change in behaviour e.g.. Walk/stop/move head/walk		
Isolation	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
	Transitional Behaviour	Number of times change in behaviour e.g.. Walk/stop/move head/walk	
Calls	Call rate per 300s		

* 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

634

635 *Data scoring and analysis*

636

637 Behaviours recorded during each test were scored using CowLog 2.0 (Hänninen and Pastell,
638 2009). A template outlining each quadrant, in addition to proximities from pen walls, novel
639 objects and pen mates, was placed over the computer screen when viewing videos for
640 consistency of scoring proximity measures. Table A.1 shows the ethogram used for each
641 personality test, and outlines all behaviours recorded along with their descriptions.

642

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

652

653 The PCA output provided the loadings of each behaviour on each principal component. The
654 loadings reflect the weight of each behaviour within the component. Only loadings of ≤ -0.3 or \geq
655 0.3 were used for reliable PC interpretation (Comrey and Lee, 2013) in addition to eigenvalues
656 ≥ 1.0 for each principle component (Zwick and Velicer, 1986). The first four PCs from the PCA
657 analysis for exploration and the first five PCs for sociability were used in the final analysis as
658 these PC's had eigenvalues ≥ 1.0 .

659

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

664 goats, $P = 0.46$; Sociability (Repeat 1), $AD = 0.33$, $n = 16$ goats, $P = 0.46$; (Repeat 2) $AD = 0.49$
665 $n = 16$ goats, $P = 0.19$). As all data was normally distributed, parametric correlations were
666 calculated to check for consistency between the repeats of each personality traits. (Pearson's
667 Correlation: Exploration $r_p = 0.826$, $n = 16$ goats, $P < 0.001$; Sociability $r_p = 0.83$, $n = 16$ goats, P
668 < 0.001). Values were consistent between repeats for both exploration and sociability. Means of
669 Repeat 1 and 2 for each personality trait were then calculated to obtain personality scores for
670 each individual goat. All statistical analyses were performed using Minitab (Release 13.1 ©
671 2000 Minitab Inc.).

672

673 *Results*

674

675 The output from the PCA performed on the exploration data for Repeat 1 and 2 revealed 4 PCs
676 with an eigenvalue greater than 1 (Table A.2). These 4 PCs for Repeat 1 and 2 explained 81.0
677 % and 82.6% of the variance respectively. According to the loadings of the behaviours on the
678 PCs (Table A.2), the first PC (PC1) reflected exploration behaviour well across both tests for
679 each Repeat (novel object and altered environment; i.e. goats that were highly explorative in
680 both tests). The following behaviours were correlated with the first PC for both Repeats
681 (loadings ≤ -0.3 or ≥ 0.3): time spent immobile exploring (for altered environment), time spent in
682 start quadrant and frequency of quadrant entered (Table A.2). Highly positive PC1 values
683 indicated goats that were explorative and spent time investigating the novel object or altered
684 environment. Highly negative PC1 values indicated goats that did not investigate the novel
685 object or environment (i.e. spent the majority of time in the start area or at the perimeter of the
686 pen). The duration of exploring the novel object or environment was shorter in these goats,
687 compared to subjects with higher exploration scores. These goats did not explore the object or
688 altered environment at all.

689

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

693 the PCs (Table A.2), the first PC (PC1) reflected sociability well across both tests for each
694 Repeat (attraction and isolation; i.e. goats that were showing increased social responses in both
695 tests, spending time touching companions during the attraction test and reacting strongly to
696 isolation). The following behaviours were correlated with the first PC for both Repeats (loadings
697 ≤ -0.3 or ≥ 0.3): time contact companion (for attraction test), transitional behaviour (for both
698 isolation and attraction tests) and call frequency (for attraction test). Highly positive PC1 values
699 indicated goats that were sociable and spent time in contact with companions. Goats with a high
700 sociability score exhibited a reduction in time spent feeding (or did not feed at all), had higher
701 rates of locomotion within the pen and an increased call frequency during the isolation test,
702 compared to goats with lower sociability scores (Table A.2).
703

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 Proximty	-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

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