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Complex contests and the influence of aggressiveness in pigs

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1 Complex contests and the influence of aggressiveness in pigs

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26 Animal contests vary greatly in behavioural tactics used and intensity reached, with some encounters
27 resolved without physical contact while others escalate to damaging fighting. However, the reasons
28 for such variation remains to be fully explained. Aggressiveness, in terms of a personality trait, offers
29 a potentially important source of variation that has typically been overlooked. Therefore, we studied
30 how aggressiveness as a personality trait influenced escalation between contestants matched for
31 resource holding potential (RHP), using detailed observations of the contest behaviour, contest
32 dynamics, and escalation levels. We predicted that winner and loser behaviour would differ depending
33 on personality. This was tested by examining 52 dyadic contests between pigs (*Sus scrofa*).
34 Aggressiveness was assayed in resident-intruder tests prior to the contest. Contests were then staged
35 between pigs matched for RHP in terms of body weight but differing in their aggressiveness. In 27%
36 of the contests a winner emerged without escalated physical fighting, demonstrating that a fight is not
37 a prerequisite between RHP-matched contestants. However, the duration of contests with or without
38 fighting was the same. In contests without a fight, opponents spent more time on mutual investigation
39 and non-contact displays such as parallel walking, which suggests that ritualized display may
40 facilitate assessment and decision making. Winners low in aggressiveness invested more time in
41 opponent investigation and display and showed substantially less aggression towards the loser after its
42 retreat compared to aggressive winners. Aggressiveness influenced contest dynamics but did not
43 predict the level of escalation. Prominent behavioural differences were found for the interaction
44 between personality and outcome and we therefore recommend including this interaction in models
45 where personality is considered. Analyses based on contest duration only would miss many of the
46 subtleties which are shown here and we therefore encourage more detailed analyses of animal
47 contests, irrespective of the level of contest escalation.

48

49 **Keywords.** Aggression, behaviour, contest, personality, pig

50

51 Animal contests are typically assessed through simple measures of contest duration and outcome
52 (reviewed by Arnott & Elwood, 2009). However, a great deal of information may be lost using this
53 approach alone, including differences in physiological state and motivation (e.g. Elwood, Wood,

54 Gallagher, & Dick, 1998). For example, on some occasions, contestants spend time in low cost
55 display behaviour after which the opponent with the lowest resource-holding potential (RHP, or
56 fighting ability) withdraws. On other occasions contestants spend the same amount of time interacting
57 but fight fiercely for that length of time, after which the opponent with the lowest RHP withdraws. In
58 the traditional approach these contests would be rated the same whereas for the contestants there is a
59 large difference in, amongst other things, physiological costs (Briffa & Sneddon, 2007). More detailed
60 analysis of contests, for example inclusion of physiological measures or analysis by phases of
61 escalation (e.g. Hsu, Lee, Chen, Yang & Cheng, 2008; Vieira & Peixoto, 2013; McGinley, Prenter, &
62 Taylor, 2015), can deepen our understanding of contest behaviour (e.g. Jennings, 2014; Schnell,
63 Smith, Hanlon, & Harcourt, 2015).

64 One situation in which a great deal of information may be lost is when confrontations are resolved
65 without escalated aggression. Many species avoid escalation where possible and contests may
66 naturally end without the occurrence of a fight or even before the opponents make contact (e.g.
67 Bentley, Hull, Hardy, & Goubault, 2009). Here, dominance is settled through threat displays (e.g.
68 Maynard-Smith & Price, 1973; primates: Judge & de Waal, 1993; pigs: Jensen, 1982). Theory
69 predicts (e.g. the sequential assessment model, SAM) that contests ending at the display phase prior to
70 escalated fighting will be of shorter duration (Parker & Rubenstein, 1981; Enquist & Leimar, 1983),
71 while those between RHP-matched individuals will be escalated and of longer duration. However, this
72 overlooks the potential importance of individual differences in behavioural tendencies that may
73 influence escalation patterns (Briffa, Sneddon & Wilson, 2015; Camerlink, Turner, Farish, & Arnott,
74 2015). Moreover, non-escalated contests are often excluded from analyses because they may count as
75 missing values, for example when outcome criteria are based on the presence of a certain level of
76 escalation. Yet, these contests may provide useful information on contest resolution (as for example in
77 Rudin & Briffa, 2011), and their exclusion has been criticised (Elwood & Arnott, 2013). Neglecting
78 contests that do not perfectly fit into theoretical or statistical models may underestimate the
79 importance of certain strategies such as conflict avoidance.

80 Firstly, contrary to current theory, we predict that within a population of RHP-matched individuals,
81 some confrontations will be resolved without a fight and that these non-escalated contests will be of

82 shorter duration. This will be tested using domestic pigs. In wild populations, pigs frequently show
83 agonistic display towards each other but damaging aggression, including fights, between adults is rare
84 (Mendl, 1995; Marchant-Forde & Marchant-Forde, 2005; D'Eath & Turner, 2009) and is
85 predominantly limited to males during the mating season (Barette, 1986). In contrast, the routine
86 mixing of groups of unfamiliar pigs in commercial husbandry results in long and injurious reciprocal
87 fights irrespective of sex, which is a considerable welfare issue (Marchant-Forde & Marchant-Forde,
88 2005). However, there are substantial individual differences in the amount of aggression (Turner et
89 al., 2006), and this variation has been related to personality (e.g. Ruis et al., 2000).

90 Secondly, we hypothesize that variation in contest behaviour (such as ritualized display, non-
91 damaging aggression, and damaging aggression) and contest intensity will be influenced by the
92 personality of the contestants. A personality trait is “a specific aspect of a behavioural
93 repertoire that can be quantified and that shows between-individual variation and within-individual
94 consistency” (Carter, Feeney, Marshall, Cowlshaw, & Heinsohn, 2013, p. 467). Personality is related
95 to many behavioural and physiological characteristics (e.g. Stamps & Groothuis, 2010), including the
96 response that an individual shows when faced with an opponent and its subsequent likelihood of
97 winning (e.g. Colléter & Brown, 2011; Melotti, Oostindjer, Bolhuis, Held, & Mendl, 2011). As such,
98 personality has recently been suggested as a component of RHP (reviewed by Briffa et al., 2015).

99 Aggression is one personality trait which can have an important role in contest behaviour. In pigs,
100 aggressiveness is commonly assessed in the resident-intruder test; a test which has demonstrated
101 considerable variation between individuals and a moderate repeatability within individuals (Erhard &
102 Mendl, 1997; D'Eath, 2004). We previously showed that aggressiveness as a personality trait,
103 measured with the resident-intruder test, influenced the initiation of agonistic behaviour during a
104 subsequent contest, although evidence that it formed a component of RHP was lacking, as
105 aggressiveness did not have a significant effect on the outcome or contest duration when an escalated
106 fight occurred (Camerlink et al., 2015). Existing contest theory (e.g. SAM, Enquist & Leimar, 1983)
107 predicts encounters between RHP-matched contestants will be maximally escalated. However, this
108 overlooks the potentially important role of variation in aggressive personality and therefore we predict

109 that variation in this personality trait will result in variation in escalation level, even between RHP-
110 matched contestants.

111 Our objective is to investigate how aggressiveness, assayed as a personality trait, of the winner and
112 loser affects contest behaviour and escalation. To achieve this, contests were analysed for the
113 dynamics and durations of all specific agonistic behaviours. We predict that 1) contrary to existing
114 theory, only a proportion of contests between RHP-matched individuals will escalate to fighting and
115 that these will be of a shorter duration; 2) variation in aggressiveness as a personality trait will result
116 in variation in escalation level, even between RHP-matched contestants; and 3) winners and losers
117 that differ in aggressiveness will show differences in their expression of contest behaviour. These
118 predictions were studied using 104 size-matched pigs. In addition we provide a detailed analysis of
119 contest dynamics to outline how certain behaviours provoke escalation.

120

121 **METHODS**

122 The study was approved by SRUC's Animal Ethics Committee and the UK Government Home Office
123 legislation ensuring compliance with EC Directive 86/609/EEC for animal experiments and adhered
124 to the ASAB guidelines. A full description of ethical considerations and methods has been detailed
125 previously in Camerlink et al. (2015) and are summarised below.

126

127 *Animals and housing*

128 A total of 114 young male and female pigs ((Large White×Landrace) × American Hampshire) from
129 17 litter groups were studied at 9 wk of age at the research farm (Easter Howgate, UK). Animals were
130 studied over three consecutive batches from April to October 2014. Piglets were kept with their sow
131 in conventional farrowing crates up to 4 wk of age. Thereafter the sow was removed and the piglets
132 remained in the crate for two more weeks. Males were not castrated and the tail and teeth were kept
133 intact. At 6 wk of age pigs were moved to the experimental facilities where they were kept with their
134 siblings in a pen measuring 1.9×5.8 m (~1.0-1.1 m² / animal). Pens had a solid floor with straw
135 bedding (~5 kg) and were cleaned daily and provided with fresh straw. Water and pelleted feed was

136 available *ad libitum*. From two weeks prior to testing all pigs were gradually (over six occasions)
137 habituated to the various test situations to reduce the possibility of fear responses during the tests.

138

139 *Resident-intruder test*

140 The resident-intruder (RI) test is an established test in behaviour research that is undertaken to obtain
141 a quantifiable measure of individual aggressiveness which is consistent over time (pigs: D'Eath &
142 Pickup, 2002). The RI test was carried out twice for each pig at 9 wk of age. An individual "resident"
143 pig was kept in a separate part of its home pen for the duration of the test (max 10 min). Then, an
144 approximately 20% smaller and unfamiliar "intruder" pig was introduced into the same compartment
145 (i.e. the resident's home pen). Under these conditions, the resident typically attacks the inferior
146 intruder within a short period of time. The latency until the first attack was recorded. If the resident
147 did not attack within 5 min after initial contact then the test was ended and the latency time was set at
148 300 s. For all pigs the test was repeated the following day with a different intruder. Residents were
149 thus tested twice for their aggressiveness. Pigs were used as either a resident or intruder but never
150 both. Intruders were used a maximum of 3 times. Test results of the second day were moderately
151 correlated with the results of the first day ($r_s = 0.58$; $P < 0.001$). Similar correlations between test days
152 have been reported previously for this test ($r_s = 0.55 - 0.73$, Erhard & Mendl, 1997). The attack
153 latencies of both test days were summed to obtain a single value of aggressiveness. Values could
154 range between 0 – 600 sec, with lower values reflecting a more aggressive response.

155

156 *Contest*

157 Contests were staged in a neutral arena between pairs of unfamiliar pigs at 10 wk of age. Opponents
158 were of similar body weight (<5% difference, i.e. matching RHP, with weight a validated measure of
159 RHP in pigs; Andersen et al., 2000; Jensen & Yngvesson, 1998; Rushen, 1987) and differing in their
160 aggressiveness as reflected in the attack latency of the RI test. Body weight ranged from 24 – 48 kg
161 (mean 34 ± 0.5 kg) and the summed attack latency ranged from 27 – 600 s (mean 257 ± 17 s). To
162 ensure a balanced difference in aggressiveness, animals were for the purpose of opponent matching
163 categorized into 'low aggressive' (summed attack latency of ≥ 360 s), 'intermediate' (121 – 359 s),

164 and 'high aggressive' (≤ 122 s). The range in attack latency that defined the bounds of these
165 categories was derived from examination of the distribution of attack latencies as a continuous
166 variable within the population. This resulted in weight-matched pigs from high against low
167 aggressiveness ($N = 16$), high-intermediate ($N = 19$), and low-intermediate ($N = 17$). Sexes were
168 matched randomly which resulted in 15 male-male contests; 12 female-female contests; and 25 male-
169 female contests. The arena was 2.9×3.8 m with a solid floor covered with a light bedding of wood
170 shavings. Opponents entered the arena simultaneously from opposite sides. The time was started from
171 the moment both had entered the arena and was stopped when a clear winner was apparent, when an
172 animal reached an end-point due to a fear response or mounting, or otherwise after 30 min. A winner
173 was recorded when one pig retreated after having received an aggressive act and failed to retaliate
174 within 2 min after retreat. The contest was recorded by a Canon Legria HF52 camera located close to
175 the ceiling. Five contests were excluded because they had to be stopped due to an end-point before an
176 outcome was reached (four were ended due to a fear response or mounting; one contest reached the
177 maximum time without a winner). This resulted in 52 contests (104 pigs of which 55 were males and
178 49 females). Ending the contest prematurely prevented any injury other than superficial skin lesions
179 due to receiving bites. Videos were observed for the duration and frequency of behaviours and the
180 sequence in which they occurred. Observations were taken by one observer using The Observer XT
181 11.5 (Noldus Information Technology, The Netherlands). The detailed ethogram of behaviours is
182 given in Table 1. For analysis of the contest escalation, four levels were distinguished based on the
183 intensity of the behaviours. These levels were I. display (non-damaging contact and low/medium
184 intensity display); II. pushing (non-damaging high intensity display); III. biting (damaging
185 low/medium intensity); and IV. fighting (damaging high intensity).

186

187 *Data analysis*

188 Data were analysed with SAS version 9.3 (SAS Institute Inc., Cary, NC, USA) using mixed models
189 (MIXED Procedure). Response variables were the proportion of contest time spent on a behaviour
190 (see Table 1 for behaviours analysed), the number of bites, contest duration, and aggressiveness in
191 attack latency (all continuous data). Residuals of the response variables were assessed for the

192 normality of their distribution (UNIVARIATE Procedure, Shapiro-Wilk statistics) and outliers
193 (Studentized residuals). Model assumptions were tested using the REG (regression) Procedure;
194 variables were tested for multicollinearity (VIF option), homoscedasticity (White test; SPEC option),
195 and independence (Durbin-Watson coefficient; DW option). To obtain normality of the residuals,
196 contest duration (in seconds) was log transformed; the behaviours investigation, nose wrestling,
197 parallel walking, pushing, fighting and bullying (analysed in proportion of contest time) were arcsine
198 square root transformed; and the number of bites (frequency) was square root transformed.
199 The mixed models had outcome status (winner or loser) as a repeated statement and contest as
200 experimental unit (SAS syntax: repeated outcome / subject= contest) to account for dependence
201 between opponents (as described by Briffa & Elwood, 2010). This specifies that the two opponents
202 within a contest (i.e. the winner and loser) are not independent of each other. The random effects were
203 batch (group of pigs at the same age) and litter (i.e. sibling group; 17 groups). The estimated random
204 effects were normally distributed (EBLUPs extracted from the mixed models were assessed
205 graphically and by Shapiro-Wilk statistic). The SAS default covariance structure (variance
206 component) showed the best fit based on the lowest Akaike information criterion (AIC) and Bayesian
207 information criterion (BIC) values compared to other covariance structures.
208 When behaviour was the response variable, the fixed factors that were included were attack latency,
209 contest outcome (winner/loser), the interaction between attack latency and contest outcome, body
210 weight, and sex (male/female). Fixed effects were stepwise removed from the models based on the
211 evaluation of the goodness of fit, choosing the model with the lowest AIC and BIC.
212 The relationship between escalation level (4 levels) and contest duration, aggressiveness, and body
213 weight was analysed with the continuous variables as response variable and escalation level as fixed
214 class effect in order to allow for the complexity of the repeated and random model structure (of which
215 the options are limited in a model with multinomial distribution) and to enable extraction of the
216 LSmeans per category. The same method was applied for fight occurrence (1/0).
217 Data are presented as least square means (LSmeans) with standard errors.

218

219 *Analysis of contest dynamics*

220 Contest dynamics were analysed through sequential analysis using The Observer XT 11.5 (Noldus
221 Information Technology, The Netherlands). Frequencies and probabilities of transitions between
222 behaviours were extracted with the State Lag Sequential Analysis for lag -1 and lag 1, which captures
223 the behaviour preceding and following the behaviour of interest respectively. Data are presented in a
224 transition map where the radius of each circle reflects either the frequency or duration of occurrence
225 of each behaviour as a percentage of the total frequency or duration of the whole contest, and the
226 widths of the arrows indicate the probability of the transition from one behaviour to the next in the
227 direction from tail to head of the arrow.

228

229 **RESULTS**

230

231 *Contest dynamics and phases of escalation*

232 Contests lasted on average 339 ± 19 s (i.e. 5 ½ min.; range 119 – 1041 s). Contests typically
233 progressed through incremental phases of intensity showing a linear escalation pattern (Figure 1). The
234 contest dynamics, however, were more complex with transitions between phases of varying intensity
235 (Figure 2). Lower-intensity behaviour could reoccur during higher escalation phases. For example,
236 within contests there were on average 2.5 fights (range 0 – 22), which shows that between fights
237 contestants paused and performed other behaviours.

238 The level of escalation was first assessed by four levels of intensity indicating the maximum intensity
239 that a contestant had shown during the contest, which was either display, pushing, biting, or fighting.

240 The level of escalation did not influence the contest duration (Table 2; $F_{3,84} = 1.39$; $P = 0.25$).

241 Contestants who engaged in mutual fighting (escalation level 4) were on average heavier than pigs

242 who only pushed or bit the opponent (Table 2; $F_{3,82} = 2.82$; $P = 0.04$). Contestants that bit the

243 opponent (level 3) were on average more aggressive than opponents whose maximum level of

244 aggression was pushing (level 2), but animals from escalation level 3 did not differ from level 1 or 4

245 (Table 2; $F_{3,84} = 2.41$; $P = 0.07$). Escalation level 1 and 2 included only few individuals ($N = 3$ and 9,

246 respectively) and therefore contests were also analysed by the occurrence of a fight as a binary trait

247 (i.e. the absence or presence of a mutual fight).

248 Out of the 52 contests, 38 contests (73%) included mutual fights and in 14 contests (27%) no fight
249 occurred but a clear winner was still apparent. Contests with a fight did not significantly differ in
250 duration from contests without a fight (with fight 337 ± 19 s; without fight 345 ± 50 s; $F_{1,86} = 0.76$; P
251 $= 0.39$). Contests were more likely to escalate into a fight when contestants were heavier (fight $35.1 \pm$
252 2 kg; no fight 33 ± 2 kg; $F_{1,84} = 5.5$; $P = 0.02$) but the fight occurrence was unrelated to the
253 contestants' aggressiveness as measured in the RI test (in attack latency; fight 253 ± 25 s; no fight 264
254 ± 36 ; $F_{1,86} = 0.09$; $P = 0.77$). The behavioural profile of the contests with a fight significantly differed
255 from the contests without a fight (Figure 1; Table 3). In contests which reached an outcome without
256 fighting a greater percentage of the total contest time was spent on parallel walking. Less time was
257 spent in the 'heads up' posture and there was less pushing. In these contests without a fight the winner
258 spent 15% more time bullying the loser than in contests with a fight.

259

260 *Aggressiveness as a personality trait affecting contest behaviour*

261 Aggressiveness as a personality trait significantly altered the behaviour of winners and losers,
262 although numerical differences in the duration and frequency of behaviours were mostly small. More
263 aggressive individuals (short attack latency in the resident-intruder test) bit their opponent in the
264 contest more frequently than individuals which were assessed as less aggressive (long attack latency
265 in RI test) ($b = -0.02$ bites / s increase in attack latency; $F_{1,82} = 5.94$; $P = 0.02$; Figure 3). Winners
266 delivered on average 13 bites more than losers (winners 18 ± 2 bites; losers 5 ± 2 bites; $F_{1,82} = 34.7$; P
267 < 0.001).

268 The most profound effects were observed for the interaction between aggressiveness and contest
269 outcome. Winners which showed little aggression in the resident-intruder test spent more time during
270 the contest on non-damaging opponent investigation (Figure 4a; interaction aggressiveness \times outcome
271 $F_{1,83} = 5.91$; $P = 0.02$), more parallel walking (Figure 4b; $F_{1,84} = 6.10$; $P = 0.02$) and tended to spend a
272 greater amount of time on non-agonistic behaviours such as walking, standing and exploring the
273 environment ($b = -0.04 \pm 0.02$ % / s increase of attack latency in losers, with winners set to 0; $F_{1,80} =$
274 3.73 ; $P = 0.06$). The most prominent difference was seen after the contest outcome was established.

275 After the retreat of the loser, winners with an aggressive personality (short attack latency) spent up to
276 75% of the contest time on bullying behaviour (unilateral biting and chasing by the winner towards
277 the loser), whereas less aggressive winners showed almost no bullying behaviour towards the losers
278 (Figure 4c; aggressiveness \times outcome $F_{1,83} = 12.60$; $P < 0.01$). Moreover, losers which were assessed
279 pre-contest as being less aggressive (long attack latency RI test) received more bullying than
280 aggressive losers.

281 The behaviours ‘heads up’, nose wrestling, shoulder-to-shoulder, pushing, and mutual fighting (means
282 provided in Table 3) were unaffected by the aggressiveness of the opponents, did not differ between
283 winners and losers, and were not influenced by the interaction between aggressiveness and contest
284 outcome (all $P > 0.10$). Heavier opponents spent less time in nose wrestling ($b = -0.20 \pm 0.1\%$ of time
285 / kg; $F_{1,81} = 12.23$; $P < 0.001$) but were more engaged in the energetically costly pushing behaviour (b
286 $= 0.62 \pm 0.3\%$ of time / kg; $F_{1,82} = 7.37$; $P < 0.01$). Sex differences were (at this age) only found for
287 pushing, with males spending considerably more time on this behaviour (males $9.0 \pm 2\%$ of time,
288 females $5.0 \pm 2\%$; $F_{1,82} = 7.73$; $P < 0.01$).

289

290 **DISCUSSION**

291 Here we show that although the duration between contests may be the same, the content of the
292 contests can differ greatly with regard to behaviour. This was most profoundly shown by the presence
293 or absence of an escalated mutual fight during a contest even though the total contest duration until
294 retreat by the loser was the same. The occurrence or not of a fight has profound effects on the
295 energetic costs and the risk of injury. This implies that within contests of the same duration the
296 specific behavioural interactions can determine completely different levels of severity.

297 Aggressiveness as a personality trait did not influence the occurrence of a fight or its outcome (as
298 shown in Camerlink et al., 2015). However, aggressiveness resulted in behavioural differences when
299 it came to the experience of victory or defeat whereby aggressive winners directed substantially more
300 damaging aggression towards the loser after retreat as compared to unaggressive winners.

301

302 *To fight or not to fight*

303 The main difference between contests was the occurrence of a fight or the absence thereof whereas in
304 both situations a clear winner and loser were present. This confirms that RHP-matched pigs can settle
305 dominance relationships without needing to fight. This finding contrasts contest theory (e.g. SAM,
306 Enquist & Leimar, 1983), as does the finding that contest duration did not differ between escalated
307 and non-escalated contests.

308 The absence of a fight in some contests, together with an increase in parallel walking, a form of
309 ritualized display, suggests that some form of assessment was made at a pre-fight phase (Mendl &
310 Erhard, 1997; Arnott & Elwood, 2009). Display behaviour such as parallel walking has been studied
311 in deer (Jennings & Gammell, 2013), where it has been suggested to aid opponent assessment (Clutton-
312 Brock, Albon, Gibson, & Guinness, 1979; Jennings & Gammell, 2013). Contestants that invest more
313 time in investigation and display may obtain more accurate information and consequently be better
314 able to assess their opponent, resulting in a decision to avoid fighting. Conversely, animals with a low
315 motivation to fight will be unwilling to escalate the contest and may therefore be expected to engage
316 in longer periods of display prior to disengagement. It is possible that both of these mechanisms have
317 a role in explaining the greater investment in display in contests that ended without a fight.

318 Contests in which the opponents avoid fighting or physical contact may occur frequently (e.g. Bentley
319 et al., 2009; Rudin & Briffa, 2011). In analyses these contests are often ignored because the read-out
320 parameters such as winning or losing may be absent or too subtle to fulfil the criteria. Elwood and
321 Arnott (2013) previously discussed the issue of differing conclusions depending on whether
322 researchers considered all contests or restricted analyses to escalated fights only. They advocated that
323 in terms of furthering our understanding of animal contest behaviour, valuable information is lost if
324 analyses are restricted to fights only. The decision to avoid fighting can be a strategy in itself
325 (Maynard-Smith & Price, 1973; Parker & Rubenstein, 1981) and this should be taken into account
326 when analysing animal contests, in particular when conclusions about assessment strategies are made.

327 The present findings reiterate the importance of studying contest behaviour in addition to the
328 traditional measures of contest duration and outcome before conclusions are drawn about the
329 assessment ability of animals.

330

331 *Effect of aggressiveness as a personality trait on contest behaviour*

332 Personality is increasingly investigated as a potential component of RHP (Briffa et al., 2015). The
333 detailed analysis of the behavioural repertoire during a contest shows that aggressiveness as a
334 personality trait had important influences on the content of the contest, with differing consequences
335 for the cost of fighting. Previously we showed that aggressiveness as a personality trait did not
336 influence the duration or outcome of the contest, but that aggressiveness provided an honest signal of
337 intent as it predicted willingness to initiate aggression in a contest (Camerlink et al., 2015). The
338 current study shows the added benefit of detailed behavioural observations in addition to traditional
339 measures of animal contests.

340 Interactions between outcome and aggressiveness in our statistical models revealed that winners
341 which had a long attack latency in the resident-intruder test, indicating low aggressiveness, invested
342 more time in non-damaging opponent investigation, parallel walking and non-agonistic behaviours
343 such as walking and exploration of the environment. These behaviours are less likely to escalate into
344 damaging aggression, as was reflected in the analysis of contest dynamics, which suggests that more
345 aggressive winners were taking more risks with their behaviour. Previously, we showed that pigs with
346 a more aggressive personality were more likely to initiate aggression, especially bites, during the
347 contest (Camerlink et al., 2015). Here we show that initiation of such behaviour has a high probability
348 of transitioning into a fight. Moreover, after victory high aggressive winners continued to exert
349 aggressive behaviour on the loser whereas low aggressive winners did not. This is in line with
350 previous work showing that high aggressive pigs are more persistent in their aggressive behaviour
351 (D'Eath, 2002). Together these results provide a consistent image that more aggressive personalities
352 are more willing to engage in fighting, shown through a willingness to attack and through persistent
353 aggressiveness. This is in line with other studies on personality, whereby animals with a proactive
354 coping style are more bold and rigid in their aggressive behaviour (Koolhaas et al., 1999; Briffa et al.,
355 2015; pigs: Bolhuis, Schouten, Schrama, & Wiegant, 2005; Melotti et al., 2011). Rudin and Briffa
356 (2012) also reported interactions between personality (boldness) and contest outcome in sea
357 anemones, whereby losers were less bold than winners. The profound behavioural differences related
358 to the interaction between personality and outcome in the current study would suggest that, where

359 possible, researchers should try to incorporate these factors into their setup and analyses. Mendl and
360 Erhard (1997) suggested that pigs differing in their aggressiveness as a personality trait may apply
361 different contest assessment strategies, and this is the focus of another study that we have conducted.

362

363 *Securing the outcome with bullying behaviour*

364 Winners with a more aggressive personality showed substantially more bullying behaviour upon
365 winning than unaggressive winners, who showed hardly any bullying behaviour. This has previously
366 been observed in groups of fighting pigs as well (D'Eath, 2002). Bullying is typically performed by
367 the dominant individual after the subordinate individual has retreated, and involves the dominant
368 animal chasing and biting the subordinate which attempts to flee (Melotti et al., 2011). Bullying is
369 more often observed in less decisive fights (Jensen, 1994) which suggest that the outcome may be less
370 clear when fights involve an aggressive animal, or that more aggressive winners have a stronger urge
371 to reaffirm the outcome, which again may relate to potential differences in assessment ability (Mendl
372 & Erhard, 1997).

373 Bullying behaviour was also considerably higher in contests without a fight as compared to contests
374 with a fight. Fighting is energetically costly, and in contests where no fight took place the winner may
375 have retained more energy to chase the loser whereas the loser may have retained more energy to flee
376 (see Camerlink et al., 2015 for the physiological costs of these fights). If the loser retained energy by
377 avoiding a fight this could also increase the chance that it would attempt to retaliate, which the winner
378 could aim to avoid by chasing the loser. Energy expenditure and reaffirmation may thus be
379 intertwined. It could be the case that similar amounts of bullying occur between contests with and
380 without a fight at a later stage when contestants have regained energy.

381

382 **CONCLUSION**

383 Contrary to predictions from contest theory, a substantial percentage of RHP-matched contests were
384 settled without a fight. However, the duration of contests with and without fighting did not differ.
385 These results highlight that RHP-matched contestants can solve conflicts by avoiding escalated
386 damaging behaviour, and these contests should be studied rather than disregarded when investigating

387 questions of assessment ability and aggressive strategies. Bullying behaviour just after the retreat of
388 the loser, which was strongly related to aggressiveness, suggests that contestants employ different
389 tactics to determine contest outcome. Given the important influence of personality on contest
390 dynamics, we recommend that, where possible, this be considered in future studies of animal contests.

391

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396

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491 determinants of fighting ability in arthropod contests. *Functional Ecology*, 27(2), 305-313.
- 492

493 **TABLES**

494 **Table 1.** Ethogram of the major behaviours recorded during the contest*.

Behaviour	Description
Investigation	Sniff or light touch to body of opponent with nose without force
Heads up	Display; Both have nose lifted high up in the air, either parallel or frontal
Nose wrestling	Both firmly press the side of their nose against the side of the nose of the other
Parallel walk	Display; Opponents walk simultaneously with the shoulders aligned
Shoulder-to-shoulder	Display; Standing or moving with the shoulder against the shoulder of the opponent without putting significant pressure on the shoulder
Pushing	Head/shoulder used to move opponent aside with pressure
Unilateral bite	Opens its mouth and delivers a bite which contacts the opponent
Mutual fight (fight)	Aggressive act, e.g. biting and pushing, which is retaliated with an aggressive act within 5 s. Continues until one retreats or until other behaviour is performed for at least 3 s.
Bullying	Unilateral pursuit including chasing, biting, or attempted biting
Withdrawal	Not retaliating to an aggressive act within 10 s after receipt. Includes a head tilt movement whereby the animal turns away its head from the opponent
Non-agonistic	Walking, standing, exploring the arena, lying, defecating, urinating or mounting (both front legs are over the back, rear, side or head of the opponent)

495 * Contest refers to the total time that two opponents were in the contest arena.

496

497 **Table 2.** Levels of escalation (I – IV) in contests between size-matched opponents.

	I. Display (<i>N</i> = 3)	II. Push (<i>N</i> = 9)	III. Bite (<i>N</i> = 16)	IV. Fight (<i>N</i> = 76)	<i>P</i> -value
Contest duration (s)	202 ± 113	333 ± 56	399 ± 63	341 ± 33	0.25
Body weight (kg)	36.7 ± 3 ^{ab}	32.6 ± 3 ^a	32.5 ± 3 ^a	35.1 ± 2 ^b	0.04
Attack latency (s)	328 ± 100 ^{ab}	320 ± 46 ^a	166 ± 53 ^b	255 ± 20 ^{ab}	0.07

498 The *P*-value refers to the difference between the four levels of escalation. *N* shows the number of pigs
 499 by their maximum level of escalation.

500 ^{a,b} Values lacking a common superscript letter differ by *P* < 0.05.

501

502 **Table 3.** Average time budgets in percentage of contest time for contests with and without a fight.

Behaviour	Average (range)	Fight (<i>N</i> = 37)	No fight (<i>N</i> = 15)	<i>P</i> -value
Investigation	4.3 ± 0.4 (0-22.3)	3.8 ± 1.0	5.8 ± 1.2	0.15
Heads up	2.4 ± 0.3 (0-10.2)	2.8 ± 0.3	1.2 ± 0.5	<0.01
Parallel walking	3.0 ± 0.3 (0-10.9)	2.6 ± 0.4	4.3 ± 0.6	<0.01
Nose wrestling	3.2 ± 0.3 (0-13.1)	2.9 ± 0.7	3.7 ± 0.8	0.12
Shoulder to shoulder	13.8 ± 0.9 (0-32.6)	14.0 ± 2.2	12.5 ± 2.6	0.42
Pushing	7.1 ± 1.1 (0-53.1)	8.6 ± 1.2	3.1 ± 2.0	0.03
Unilateral biting (n bites)	11.6 ± 1.3 (0-66)	12.8 ± 2.0	8.0 ± 2.9	0.10
Mutual fighting	10.7 ± 1.0 (0-39.0)	14.9 ± 1.8	0.0 ± 0	.
Bullying	12.5 ± 1.8 (0-74.7)	8.2 ± 2.6	23.4 ± 3.6	<0.001
Non-agonistic	43.0 ± 1.8 (5.4-87.7)	42.3 ± 3.0	46.0 ± 4.1	0.36

503

504 **FIGURE CAPTIONS**

505

506 **Figure 1.** Average latency (with standard error bars) after entering the arena at which the first
507 occurrence of the behaviour listed on the x-axis was observed, displayed for contests with and without
508 a fight.

509

510 **Figure 2.** Transition map of behaviours during dyadic contests. The circle radius indicates the relative
511 duration or frequency of occurrence (durations of <3 sec or frequencies of on average <1 have the
512 same radius). The colour groups the behaviours into overarching categories of intensity (from white
513 (non-damaging investigation) to dark grey (damaging behaviour)). Arrow widths indicate the
514 probability of the transitions. Transitions with a probability <0.10 are not displayed.

515

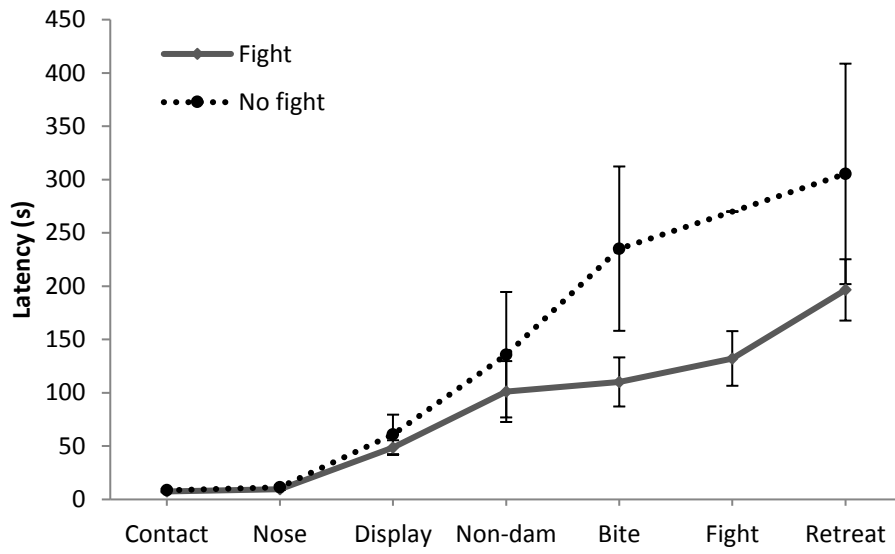
516 **Figure 3.** Number of unilateral bites (delivered outside fights) by winners and losers differing in
517 aggressiveness reflected in attack latency. Winners are depicted in black circles and a solid trend line
518 whereas losers are depicted in open circles and a dashed trend line.

519

520 **Figure 4 a – c.** The percentage of contest time spent on non-damaging investigation, parallel walking
521 and bullying behaviour by winners and losers differing in aggressiveness as reflected by attack
522 latency. A shorter attack latency reflects greater aggressiveness. Winners are depicted in black circles
523 and a solid trend line whereas losers are depicted in open circles and a dashed trend line. The
524 percentage of bullying for winners indicates the amount of time spent in chasing the loser whereas for
525 the losers it means the time spent fleeing from the attacks of the winner.

526

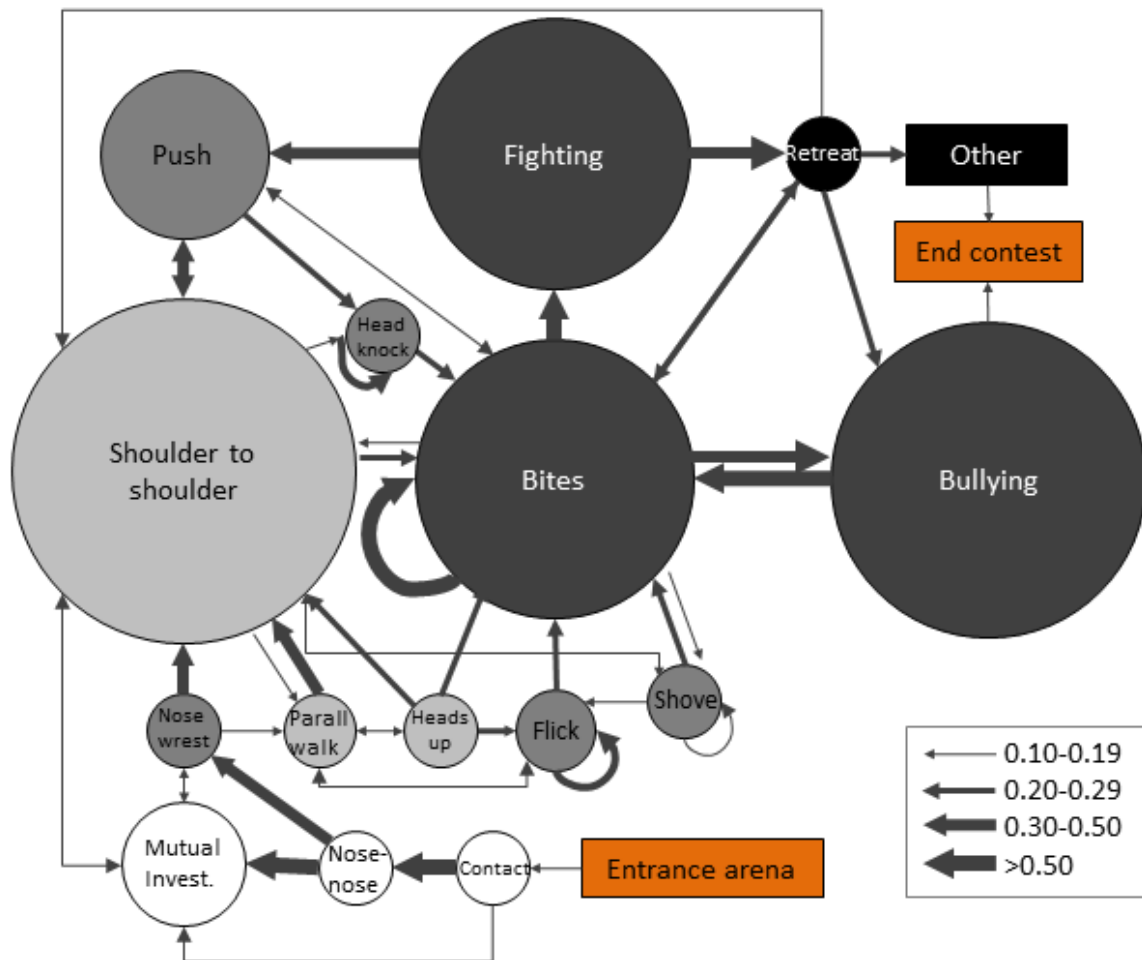
527 **Figure 1**



528

529

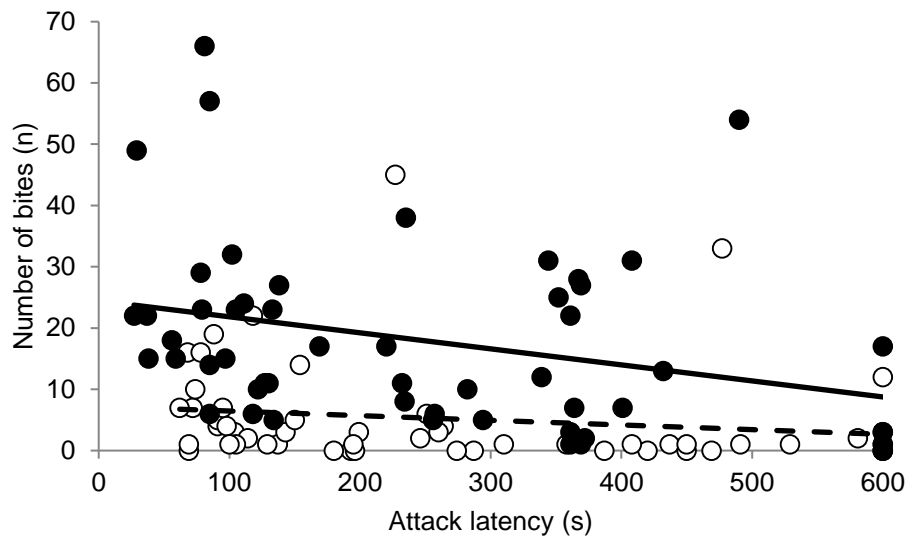
530 **Figure 2**



531

532 **Figure 3**

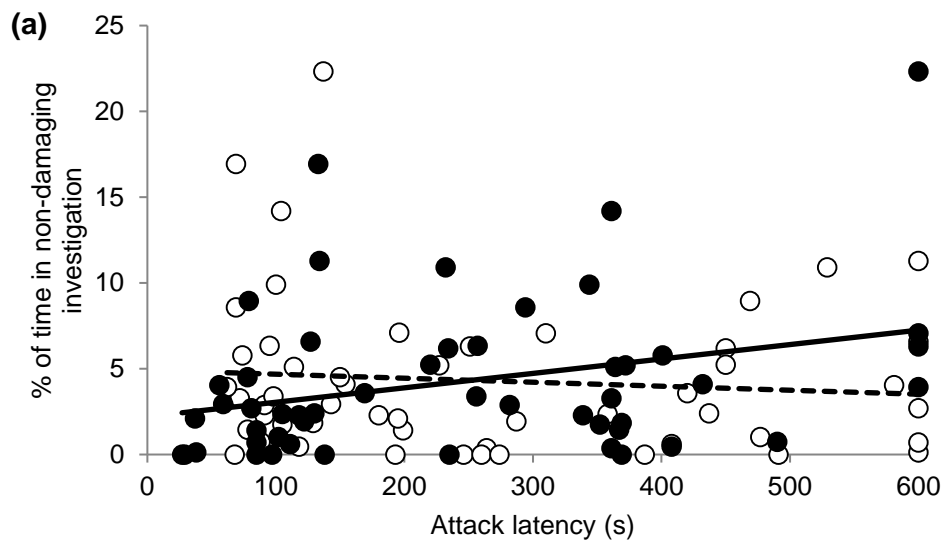
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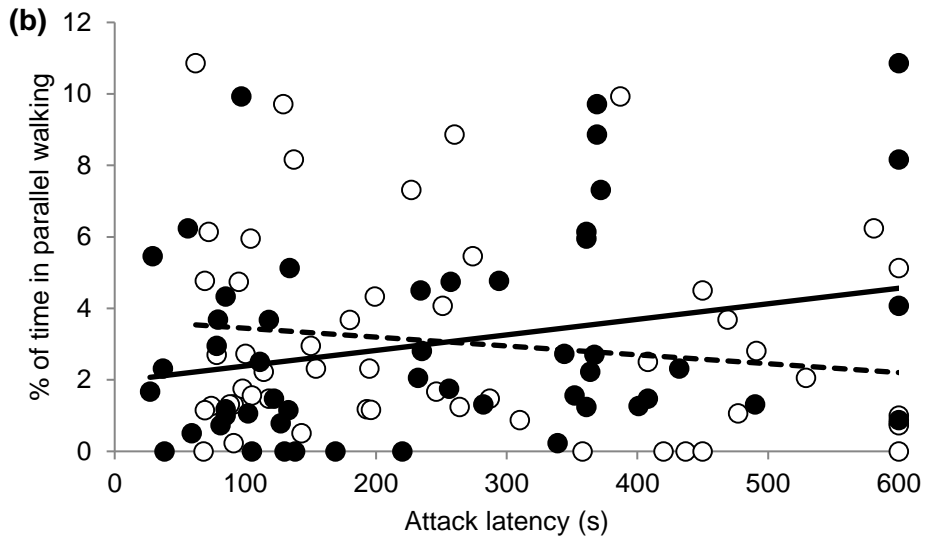
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536 **Figure 4 a – c**



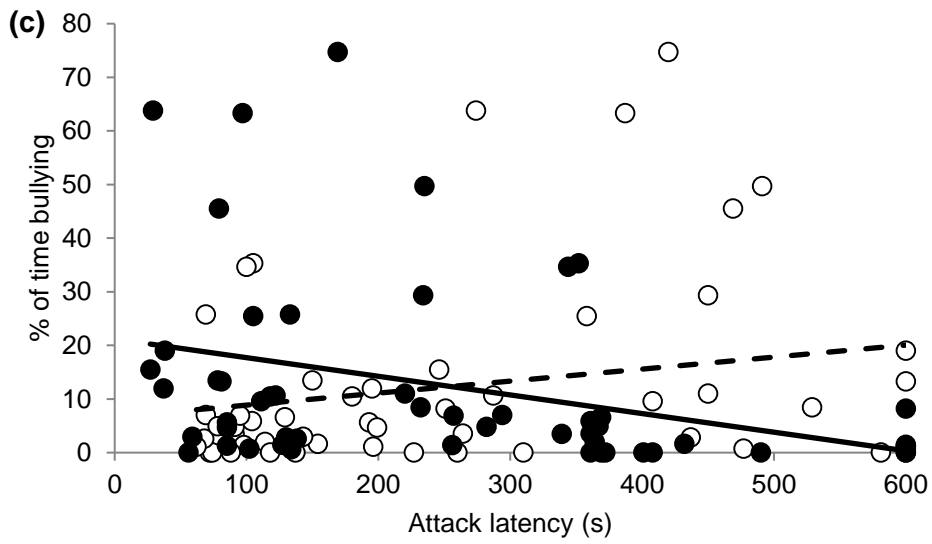
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