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Inhibitory control – important trait for explosive detection performance in police dogs?

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Abstract

Working dogs are used for a range of important operational tasks. However, there is little knowledge on the possible association between cognitive traits and the actual working dog performance. This study investigated whether motor inhibition, persistence, problem-solving strategies, and spatial problem-solving are associated with explosive detection success in specially trained police dogs. Dogs (N = 24) were tested with a cognitive test battery, and subsequently they participated in an explosive detection test. The explosive searching situation and the location of the test was such that it would reflect as much as possible a real-life situation. Canine handlers also filled in a questionnaire regarding their dog's working behaviour. We found that those dogs that were more successful in explosive detection task had better motor inhibition in a cylinder task compared to dogs with lower success in an explosive search task. Furthermore, we found that dogs that made more errors in the cylinder task were generally more likely to give up searching sooner, as reported by their handlers,

25 and also abandon sooner the problem-solving task in behavioural test. This study suggests that
26 inhibitory control, specifically motor inhibition, may be an important aspect to consider when
27 selecting suitable dogs for explosive detection tasks.

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33 Introduction

34 Stable individual differences in cognitive abilities are found in humans (Corr, 2010), and have also
35 been documented in nonhuman animals in recent years (Corr, 2010; Griffin et al., 2015; Brucks et
36 al., 2017). Cognitive abilities, such as behavioural inhibition, associative learning, problem-solving,
37 and attention are important traits for academic success in humans (Moffitt et al., 2011), but little is
38 known of the consequences of cognitive variation for canine working success. Several studies have
39 focused on identifying potentially successful working dogs as early as possible because all forms of
40 dog training (e.g. military, guide, police, assistance dog, drug detection, explosive detection) is costly
41 (Wilsson and Sundgren, 1998; Sinn et al., 2010; Tomkins et al., 2011). At the moment rejection rates
42 in training programmes can be as high as 46–50% (Ennik et al., 2006). The majority of studies, and
43 personality test batteries used in the selection process for working dog training, focus on testing
44 personality traits such as shyness - boldness, trainability, activity, aggression and sociability. The
45 significance of cognitive traits in dogs in relation to working dog success has been assessed, to our
46 knowledge, only in two studies. In guide dogs, the authors found that both the personality
47 (temperament) and the problem-solving traits were important in determining the success in guide
48 dog program (Bray et al., 2017). In a more recent study, the likelihood of engaging in eye contact
49 with the experimenter was found to be important for the success in assistance dog (MacLean. and
50 Hare, 2018) . For the explosive search dogs, instead, the researchers found that traits such as a
51 short-term memory and the sensitivity to human communicative signals were important (MacLean
52 and Hare, 2018) . However, in their study, their assessment of the “success” in explosive search was
53 based on the trainer’s opinion from these dogs from the training period. In this study, instead, we
54 used a measure of success, which reflects closely a real explosive search situation. We also
55 developed a short cognitive test battery (approximately 20 min/ dog) including tests measuring
56 dog’s inhibitory control, persistence, problem-solving strategy, and spatial problem-solving, and

57 measured the dog's success in explosive search. In addition, we asked handlers opinion on their
58 dogs general working performance.

59

60 Poor inhibitory or self-control has been shown to be associated with poorer cognitive performance
61 both in dogs (Müller et al., 2015) and in humans (Duckworth 2015). Inhibitory control can also be
62 observed as an activity in the same brain areas (frontal brain region) in humans and in dogs (Cook
63 et al., 2016). In dogs, impulsivity has been shown to be a stable trait over time (Riemer et al., 2014).
64 High impulsivity may predict behaviour problems in dogs (Wright et al., 2012) and increase the risk
65 of externalizing disorders in humans. Individuals with good self-control can better regulate their
66 behavioural, emotional, and attentional impulses compared to more impulsive individuals
67 (Duckworth and Kern, 2011). Inhibitory control, a major part of self-control, is the ability to inhibit
68 prepotent or impulsive, but ultimately counterproductive behaviour (de Ridder et al. 2011). In
69 animals, inhibitory control is necessary, for example in cooperative hunting or when living as a
70 subordinate member in a hierarchical group (Marshall-Pescini et al., 2015). The ability to know when
71 to hold back, and when to join in cooperative group hunting, may be an important factor for the
72 success of the hunt (Marshall-Pescini et al., 2015) . Inhibitory control has been measured in humans,
73 as well as in many animal species, dogs included (Verbruggen, 2009; Maclean, Evan et al., 2014;
74 Mayack and Naug, 2015) . Impulsivity is a complex trait, which is divided into two overlapping
75 concepts: impulsive choice and impulsive action (Diergaarde, 2008).

76 Several tasks have been used to measure inhibitory control in animals. Majority of these tasks do
77 not correlate with each other, and those seem to reflect different aspects of inhibitory control
78 (Brucks et al., 2017; Vernouillet et al., 2018) . In this study, we chose to measure impulsive action
79 using the cylinder task (Bray et al., 2014) . In the cylinder task, the dogs are first trained to retrieve

80 a reward out of an opaque cylinder, which is open on both ends. After several training trials, the
81 cylinder is made transparent, and the dogs could see the reward inside. To get access to the
82 reward they need to go to the sides of the cylinder and inhibit reaching for the reward directly (by
83 touching the glass). Cylinder task was chosen as we wanted a method, which has been used in
84 variety of species (Maclean et al., 2014), and most importantly, does not need lengthy training
85 period. Any task that requires lengthy pre-learning periods, may actually accidentally exclude the
86 most impulsive individuals, as the poor impulse control most likely slows down the learning
87 process. V-detour task has been suggested to measure spatial problem-solving ability, but also
88 inhibitory control (Marshall-Pescini et al., 2015) and this task was also included in the cognitive
89 test battery. In the V-detour-task, the dogs are required to walk away from the food reward and
90 first make a detour around a V-shaped fence to reach a reward.

91 Delayed gratification task has been often used in measuring inhibitory control. However, in dogs, it
92 has recently suggested to measure the persistency in focusing on the higher value/delayed reward
93 (Brucks et al., 2017) . This test was also found to correlate negatively with tests measuring more
94 spontaneous motor inhibition and with impulsivity scores derived from same dogs (DIAS, Dog
95 Impulsivity Assessment Scale) (Brucks et al., 2017). It was also suggested to measure more
96 motivation than inhibitory control, and due to these above-mentioned factors, this task was left
97 out from the test battery.

98

99 In addition to good inhibitory control, traits most likely important for an explosive search dog are
100 the ability to work and solve problems independently and persistently. However, the dog also needs
101 to be guided and controlled during search, and thus complete independency, as a problem-solving

strategy, might not be optimal. An “impossible” or “unsolvable task” has frequently been used with dogs to test the dog’s tendency to seek help or look back towards humans (Miklósi et al., 2003). In this type of task, dogs are confronted with a box, which is easy to open at first, but which finally becomes impossible to open. Dogs vary a great deal in the main strategy they use to try to open the box; some are independent while others are quick to seek help from humans by gazing in their direction. The time spent gazing towards humans for help has been found to have a relatively large heritable component (h^2 0.37) (Persson et al., 2015), and several loci through GWAS (Genome-Wide Association) studies have also been indicated for this behaviour (Persson et al., 2016). An independent problem-solving strategy has been interpreted as persistence in a recent study, where wolves were suggested to be more persistent compared to dogs when tackling an unsolvable task (Marshall-Pescini et al., 2017). Persistence is a trait that is highly associated with good self-control and with a conscientiousness personality trait in humans, especially in children (Caspi et al., 2005). Generally more studied in humans (Baer et al., 2015), persistence has only recently raised interest in canine studies (Dalal and Hall, 2019) . Persistence is most likely a trait that varies tremendously between individuals as well as between dog breeds, yet a methodology for reliably testing persistence in dogs is lacking.

This study investigates whether the individual variation in the canine cognitive traits of inhibitory control, persistence, problem-solving strategy, and spatial problem-solving correlate with work performance in Finnish police dogs specifically trained for explosive detection. Our hypothesis is that more persistent dogs with good inhibitory control perform better in the explosive detection task.

Materials and methods

126 A total of 24 trained and healthy Finnish police explosive search dogs participated in the study. The
127 age of the dogs varied between 12 and 112 months (mean age 58 months), and they represented
128 five breeds (eleven Belgian Shepherd Malinois, eight German Shepherds, three Labrador retrievers,
129 one English springer spaniel and one Dutch Shepherd mix). Only two of the tested dogs were
130 females. 18 dogs were dual purpose dogs (i.e dogs trained both for explosive detection and attack
131 / protection) and only five dogs were single purpose dogs (trained only for explosive detection).
132 All of the dogs were first tested with a short cognitive test battery, which was conducted for 23 dogs
133 at the Finnish Police Dog Training Center (Hämeenlinna), and for one dog in Vantaa. Police dog
134 handlers also filled in a questionnaire on the dog's daily routines, performance in searching in actual
135 work, arrival age, amount of weekly training, handler experience, and so forth. Finally, all dogs
136 participated in annual qualification test to monitor each dog's explosive searching abilities.

137

138 *Behavioural test*

139 Each dog was assessed using a short cognitive test battery including a cylinder test, a V-detour and
140 an unsolvable task. Food (sausage, 1.5 cm x 1.5 cm) was used as reward in each task. The dog was
141 released into the test room, and was allowed freely to explore the room (approximately 5min) while
142 the handler filled out the dog's information sheet. During the test, only the experimenter (KT), dog
143 handler and a dog were present in the room.

144

145 *Behavioural test - Cylinder task*

146 Cylinder test was done according to Bray et al. (2014), however, the major difference in the methods
147 was, that the dog saw the food entering the cylinder, both in the learning and in the test phases. In
148 the learning phase, the dog is taught that the opaque cylinder contains food, and that the dog is
149 able to get the food from the open end of the cylinder (25 cm wide, with 20 cm opening) (Fig 1a).

150 Dog is called by its name to get its attention, and food is shown to the dog, and then placed into the
 151 cylinder. Experimenter then gives the permission to the handler to release the dog. In both the
 152 learning and the test phase the dog is released from 180 cm distance from the cylinder, and the dog
 153 sees the food entering the cylinder. The criteria for successful learning was 4 correct attempts
 154 (taking food without touching the cylinder) out of 5 trials, where the maximum trials in the learning
 155 phase was set to 15. Only one dog (Malinois) did not pass the learning phase, and was thus excluded
 156 from the analysis of cylinder test. After successful learning, the cylinder is made transparent, and
 157 consequently, the dogs can see the reward inside (Fig b). In the actual test phase, the food was
 158 placed inside the transparent cylinder ten consequent times, and the dog's success and errors were
 159 counted. An error occurred when the dog attempted to reach the food directly through the
 160 plexiglass (i.e. by touching the glass with either its paw(s) or nose), which is considered to reflect
 161 poor inhibitory control. Success in this task varied from 0% (errors in all ten trials) to 100% (no errors
 162 made in ten trials).

163

164 *Behavioural test - V-detour*

165 In the V detour task (Pongrácz, 2001) , the dog was allowed to see when the food was placed
 166 inside a V-shaped fence, into the narrow end of the V-detour. The length of both sides was 180
 167 cm, and height of the fence was 69 cm, and dog could see the food through the fence (Fig 1c). The
 168 experimenter places the food by leaning over the fence (i.e. not going inside the fence).
 169 Immediately after the placement of food inside the fence the dog was released from
 170 approximately 40cm distance from the narrow end of fence. The experimenter stands beside the
 171 fence facing the fence (Fig 1 c). To successfully reach the food, the dog has to move further away
 172 from the food, and make a detour successfully to reach the food. It has been suggested that
 173 individuals with lower inhibitory control will be unable to fight their desire to head straight for the

174 food, an unproductive choice that results in more time elapsing before they ultimately reach the
 175 treat (Marshall-Pescini et al., 2015). The time it took for the dog to reach the food inside the V-
 176 detour at the first attempt was measured (Bray et al., 2015), keeping the maximum time to three
 177 minutes. There was only one trial for each dog.

178

179 *Behavioural test - Impossible task*

180 Finally, the dogs were tested with the impossible task paradigm, whereby the methodology is
 181 followed according to previous studies (Miklósi et al., 2003). In this task, the dog is initially
 182 confronted with an easy problem-solving task (removing a piece of sausage from a transparent
 183 plastic box three times). In the first three trials, the lid of the box is not locked on its bottom, and
 184 therefore is easy to push aside and reach the food. On the fourth occasion, the task looks similar,
 185 but the lid of the box is now locked to the bottom, and impossible to open (Fig 1 d). Also, the amount
 186 of sausage inside is 10 pieces (in the training trials it is one piece) to ensure the motivation in the
 187 task. During the subsequent two-minute period, *three* categories of behaviours were measured: 1)
 188 the time that the dog spends manipulating the box with its nose or paw(s), (i.e. independent
 189 strategy, previously interpreted as persistence in Marshall-Pescini et al. (2017) ; 2) the time spent
 190 looking at the tester / handler OR looking back and forth between the tester / handler and the task
 191 OR trying some other previously learned tasks, such as lying/sitting AND looking either tester /
 192 handler or the box (i.e. human-dependent strategy); and 3) abandoning the task – sniffing the
 193 ground, running around, exploring the room, not focusing on either the humans or the box (i.e.
 194 giving up, negatively correlated with persistence). We calculated the seconds for each of the three
 195 behaviours during the two-minute period, and the percentage of each three behaviours was
 196 subsequently used in the analysis.

197

198 *Qualification test*

199 Finally, all of the dogs participated in an annual explosive search test, which is an official test of
200 Finnish Police to monitor each dog's explosive searching abilities. This qualification test was planned
201 and evaluated by the teacher at the Finnish Police Dog Training Center (AT). This annual qualification
202 test was conducted two months after the cognitive testing, and included 12 different explosives
203 hidden in two large buildings (local school). The search test in these two locations was divided into
204 two separate days. The searching situation and location was such that it would reflect as much as
205 possible a real-life situation. The dog needed to find at least eight of the 12 explosives in order to
206 continue working as an explosive detection dog. Success in the test was rated based on the number
207 of found explosives (numerical value ranging from 0 to 12). Also "false positives" were recorded
208 (false positive = dog clearly indicates that it found an explosive, handler approves dog's signalling,
209 but there is no explosive at that location).

210

211 *Questionnaire and data analysis*

212 Police dog handlers were asked to complete a questionnaire prior to the annual qualification test.
213 The questionnaire included questions on the dog's daily routine, background, training, general
214 working performance and behaviour (Attachment 1). Specifically, we were interested on how does
215 the owner perceive the dog's working abilities (persistence, independence, ability to guide the dogs
216 search, asking for help, and giving up). Also, we asked owner evaluation on the dog's sociability
217 (friendliness), sudden aggressive behaviour, ability to calm down, and police-car related stress
218 behaviour. Part of the questions in the questionnaire were derived and modified to suit for search
219 task from an earlier published questionnaire (Wright et al., 2011; Tiira and Lohi, 2014) .

220

We were interested to find out whether any of the measured variables in the behavioural test, or in the questionnaire were associated with success in the explosive search test. We used Spearman's Correlation Coefficient to analyse the correlation between success in the explosive search task, the behavioural test variables and the questionnaire variables. Correction for multiple testing was done using Benjamini-Hochberg procedure (Benjamini, 1995) using a critical value for discovery rate as 0.10. Corrected values are presented.

Results

A total of 23 dogs participated in the behavioural test battery, 25 into the qualification test and 23 handlers answered the questionnaire. The number of dogs that we had data from both behavioural test battery and qualification test was 23. However, one dog was left out from the analysis of the cylinder task, due to not learning the first cylinder phase, thus leaving the sample size for the cylinder task analysis $N = 22$. In addition, in the impossible task, six dogs broke the plastic box before 2min period ended, and thus reached the food. As we do not have the data from the whole 2 min period, we felt that it was safe to exclude all these individuals from the later analysis of the impossible task, thus leaving the sample size for the impossible task as 17. The mean values for variables investigated are presented in the Table 1. In two occasions at the qualification test, the dogs' performance was interrupted by the handler or the judge (as the dog was unable to concentrate on searching). These dogs were included in the analysis and the number of found explosives was set 0 for these dogs.

244 Success in the cylinder task was the only factor that was significantly associated with success in the
 245 explosive search task. Dogs that had a high success rate in explosive detection had fewer errors in
 246 the cylinder task compared to dogs with a low success rate (Spearman's correlation coefficient $r_s =$
 247 0.466, $P = 0.033$, $N = 22$, Fig. 2). The percentage that each dog spent on using different problem-
 248 solving strategies (independent $P = 0.463$; human-dependent $P = 0.975$; abandoning the task, giving
 249 up $P = 0.556$, $N = 17$), was not associated with the search task success. The search task success was
 250 not associated with the time taken to solve the V-detour ($P = 0.681$) either. The handler's
 251 assessment of the dog's general working abilities (persistence $P = 0.80$, giving up $P = 0.945$,
 252 controllable $P = 0.846$, asking for help $P = 0.059$) was not associated with success in explosive
 253 searching. However, the number of errors (false positives) in the explosive search task was
 254 associated with the handler's evaluation on the dog's persistence ($r_s = 0.460$, $P = 0.030$, $N = 23$),
 255 where dogs evaluated by their handlers as more persistent also made more errors in the explosive
 256 search task. Everyday routine variables (amount of training $P = 0.419$, daily exercise $P = 0.853$) or
 257 age ($P = 0.151$) were not associated with success in the search task.

258

259 There were, however, several significant correlations between owner assessment of a dog's
 260 working abilities and behavioural test variables. Those dogs that made more errors in the cylinder
 261 task tended to be evaluated by their handlers as giving up sooner in the explosive search ($r = -$
 262 0.446, $P = 0.053$, $N = 21$), and these dogs also abandoned the impossible task box more easily ($r = -$
 263 0.518, $P = 0.040$, $N = 16$), thus being less persistent. Dogs that abandoned the impossible task box
 264 for longer periods, were also estimated to give up easily during the search by their handlers ($r =$
 265 0.515, $P = 0.044$, $N = 16$). Furthermore, the time that the dog spent trying to open the box
 266 (independent strategy) was *positively* associated with the handler-evaluated tendency to give up
 267 during the explosives search ($r = 0.595$, $P = 0.019$, $N = 16$). Moreover, human-associated strategy

was negatively correlated with handler-evaluated tendency to give up during a search; human-oriented dogs were evaluated as less likely to give up ($r = -0.766$, $P = 0.007$, $N = 16$).

Several handler-evaluated traits in the questionnaire were also correlated with each other. Dogs that were trained less (per week) were also evaluated to be more likely to give up during a search ($r = -0.710$, $P = 0.004$, $N = 23$). Dogs asking more help (handler-evaluated trait) had difficulties in calming down at home ($r = -0.448$, $P = 0.037$, $N = 23$), were more likely to give up during search ($r = 0.428$, $P = 0.048$, $N = 23$), and had more aggressive behaviour ($r = 0.467$, $P = 0.023$, $N = 23$). Dogs that were evaluated as being more persistent in search were also evaluated to be easily controlled during search ($r = 0.576$, $P = 0.01$, $N = 23$).

We also observed breed differences in the cylinder task; Malinois ($N=10$) made fewer errors compared to German Shepherds ($N=6$) (Mann-Whitney U test, $P = 0.015$). There was also a tendency for Malinois to experience better success in explosive detection (Mann-Whitney U test, $P = 0.056$), and to do less errors (false positives) during the explosive search test (Mann-Whitney U test, $P = 0.020$). The datasets generated during and/or analyzed during the current study are available from the corresponding author upon request.

Discussion

Self-control has been among the most widely studied subjects in human social sciences in recent decades (Duckworth, 2015). In humans, good self-control is associated with lifelong benefits in several areas of life (Moffitt et al., 2011), but little is known about the performance of dogs with variable inhibitory control. We found that explosive detection dogs with good inhibitory control,

(fewer errors in the cylinder task), were more successful in explosive detection, as expected, and were also evaluated by their handlers as being more persistent in general when it came to search tasks. This is the first time that an association has been found between working dog success and inhibitory control with dogs. A recent study, that also investigated the association between cognitive traits and explosive search success, did not find any association between the cylinder task and dog's performance (MacLean and Hare, 2018) . As a measure of dog's performance, the authors used "various training and performance-related records" which were obtained from the dog trainers (MacLean and Hare, 2018) . Our measure of dog's working performance was resembling as closely as possible the real-life situation of an explosive search dog. In general, we feel that the studies investigating the working dog "performance" should have more accurate measures of performance, that reflect the actual working success, and not the trainability of the dog. Moreover, there is most likely a large difference between the different types of dogs (pet and police dogs) and different breeds in the performance in the cylinder task. The average cylinder task success in our study with police dogs was 66.8 %, while in the earlier studies with pet dogs, the average success was 82 % (Vernouillet et al., 2018) or even 95 % (Marshall-Pescini et al., 2015) . In dogs, inhibitory control most likely has a heritable component (Fadel et al., 2016) , but it is also context dependent and can be affected by training and experience (Glady et al., 2012). Recent selection, as opposed to historical selection, is pronounced in the behavioural profiles and personalities of contemporary dog breeds (Svartberg, 2006). Many dog breeds are clearly divided into two separate breeding lines, whereby in work-line breeding, the major breeding criterion is success in actual work (police, customs, hunting etc.) or success in working dog competitions. Correspondingly, in show-line breeding, appearance and success in dog shows are the most important criteria for breeding, and most pet dogs belong to the show-line. Selection in working dog breeding lines has favoured impulsive behaviour (Fadel et al., 2016), as well as hyperactivity (Foyer et al., 2014) . An easily aroused dog,

316 which behaves without hesitation, is most likely easier to train for tasks that demand risky
317 behaviour, such as protection or certain hunting tasks (e.g. cave hunting dogs, which must confront
318 a much larger animal in a confined space) (Brady et al., 2018) . Hyperactive-impulsive dogs also seem
319 to have a higher reward responsiveness (Gerencser et al., 2018), which is a very useful trait in dog
320 training. The most popular police dog and working dog breeds (working line), Belgium Shepherd
321 Malinois and German Shepherd, may thus have a lower inhibitory control compared to pet dogs due
322 to selective breeding. Low inhibitory control is most likely very suitable for protection and attack,
323 however, may not be ideal for longer working tasks, which demand stamina and the ability to work
324 with a lower arousal level. Also, highly aroused dogs pant more than calm dogs, and as olfaction and
325 panting have an inverse relationship (Jenkins et al., 2018) , panting due to high arousal may reduce
326 the ability to smell. Moreover, in an earlier study, the canine problem-solving ability was shown to
327 be worse in dogs, with low inhibitory control, compared with dogs with better inhibitory control
328 (Müller et al., 2015). Defects to inhibit impulsive actions may also worsen the ability to concentrate
329 on the odour related task in the qualification task.

330

331 Inhibitory control has been measured in humans (Duckworth and Kern, 2011) as well as in dogs
332 (Brucks et al., 2017) using various approaches (behavioural tests, questionnaires). In both species
333 the main finding has been that the different measures do not correlate with each other, and most
334 likely measure different aspects of inhibitory control. Inhibitory control appears to be a complex
335 trait, and as different tests seem to measure different aspects of this ability, practitioners have
336 been cautioned against using a single task as a measure of inhibitory control (Brucks et al., 2017) .
337 The V-detour, a task also suggested to measure inhibitory control, did not correlate in our study
338 with success in the explosive search task, nor with the cylinder test success. Lack of correlation

339 between the V-detour and the cylinder task has also been observed before (Marshall-Pescini et al.,
340 2015) . The reason for the lack of correlation between different tasks (and questionnaire(s)) might
341 be that those evaluate different inhibitory control abilities, and furthermore, are most likely
342 context specific (Vernouillet et al., 2018) .

343

344 The cylinder task errors demonstrating counterproductive behaviour, such as the dog touching the
345 plexiglass in consecutive trials with their nose and paw(s) in order to access food, have recently been
346 interpreted as indicating persistence in dogs (Brucks et al., 2017). Our results do not support this;
347 dogs with fewer cylinder task errors were evaluated by their owners as being more persistent in real
348 working tasks, and these dogs were also less likely to abandon the impossible task box. Moreover,
349 these dogs had better success in the explosive search qualification test – a task that demands real
350 working persistence. The personality trait of conscientiousness in children associates with individual
351 differences in self-control (Caspi et al., 2005; Duckworth and Seligman, 2017). One of the traits in
352 highly conscientious children is persistence (Caspi et al., 2005), this suggesting that persistence in
353 animals also most likely correlates with good inhibitory control, as was also found in our study. Also,
354 one of the definitions of impulsivity is the lack of perseverance, which means the difficulty of
355 focusing on a task that may be boring or difficult (Roberts et al., 2011) . The term persistence should
356 not be conflated with inflexibility in changing from unadaptive behaviour to more appropriate
357 behaviour, due to a high arousal state. We feel that this inflexibility in behaviour regulation is most
358 likely the explanation for high number of errors in dogs. Dogs with higher basal arousal level most
359 likely perform worse in a problem-solving task when arousal level is increased (Bray et al., 2015).
360 We suspect, that, in our study, the dogs with high number of errors in the cylinder task most likely
361 also have a higher basal arousal level. This, however, needs more research.

362

363 Against our hypothesis, the dog's persistence, measured in the impossible task was not associated
364 with the success in the explosive search task. There are several possible explanations for this; (1)
365 either persistence is not an important trait for this task, (2) there is no variation in the persistence
366 in the study population, (3) the sample size in this task was too small (N=17) or finally (4) the
367 impossible task's independent strategy does not measure persistence. We feel, that together with
368 the small sample size, the latter explanation might be the most likely one. The impossible task has
369 been used in several studies assessing dogs' problem-solving strategies, with human gazing being a
370 particular the focus of interest (Miklósi et al., 2003; Passalacqua et al., 2013; Marshall-Pescini et al.,
371 2017). Behaviour in this task can be divided into three main categories. First, the dog can
372 independently try to open the box (independent strategy). Second, the dog seeks for help either by
373 gazing at humans, looking back and forth between humans and the box, or doing a previously
374 learned task such as sitting, barking, and so on. All of these human-focused strategies were
375 combined in this study under a human-associated strategy, which is an *active* strategy whereby the
376 dog attempts to open the box by using human help. Finally, the dog can also choose to abandon the
377 box (i.e. by going away, or exploring the room). An independent strategy has recently been
378 interpreted as persistence and human-associated gazing as giving up (Marshall-Pescini et al., 2017).
379 Contradicting this hypothesis, in the present study the independent strategy was associated with
380 the tendency to give up searching (handler assessment) and, correspondingly, the human-
381 associated strategy was strongly correlated with less likelihood of giving up (handler assessment).
382 However, abandoning the box (not focusing on the box at all) was associated with the handler's
383 evaluation of dog's tendency to give up, and we suggest that this could be used in the future to
384 measure the likelihood of giving up in a task. The inability to switch from an unsuccessful strategy
385 in the impossible task (independent strategy) to an alternative one (seeking help from humans) may

386 not actually reflect persistence, but inflexibility due to a highly aroused state. However, this calls
387 for more research using a larger study population with more genetic variation (different breeds).
388 The study population and its genetic variation (breeds) most likely has a large influence on results
389 in canine cognitive studies, especially with small sample sizes.

390

391 We also found that the Malinois breed made fewer errors during the cylinder task, and these dogs
392 also tended to have better success in the explosive search test. The data, however, was very small
393 for each breed, and should therefore be treated with caution and replicated with a larger dataset.
394 This study, suggests that inhibitory control may be one important aspect to consider when selecting
395 suitable dogs for explosive detection. Working dog success should be in the future be assessed using
396 methods that reflect the actual working ability, and not trainability. Most typically canine cognitive
397 studies focus on small group of dogs originating from several breeds, which is a major source of
398 mixed results. Canine cognitive studies, which have objective cognitive test-data, and large sample
399 sizes from different breeds are crucially needed.

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401

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405

406 **Ethical approval**

407 All procedures performed in studies involving human participants were in accordance with the
408 ethical standards of the institutional and/or national research committee and with the 1964

409 Helsinki declaration and its later amendments or comparable ethical standards. All applicable
 410 international, national, and/or institutional guidelines for the use of animals were followed.

411

412 Declaration of interest

413 This work (for K.Tiira) was financially supported by the Police Dog Training Centre. Authors have
 414 no competing interests to declare.

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Table 1. Descriptive statistics (sample size, mean and standard deviation) of the variables in explosive qualification task, behavioural test and questionnaire.

Variable	N	Mean	SD
Found explosives (qualification task)	25	8.40	2.86
False positives (qualification task)	25	1.36	1.22
Cylinder, % (Behavioural test)	22	66.80	23.10
V detour, s (Behavioural test)	23	31.26	39.80
Independent strategy, %(Impossible task, behavioural test)	17	45.08	28.65
Owner dependent strategy, % (Impossible task, behavioural test)	17	43.79	33.10
Abandoning the box %(Impossible task, behavioural test)	17	11.03	19.79
Dogs persistency at work (Questionnaire, 1-5)	23	3.74	0.69
Dogs tendency to ask for help (Questionnaire, 1-5)	23	2.61	1.08
Dogs tendency to give up (Questionnaire, 1-5)	23	2.30	1.15
How easy it is to control the dog during search (Questionnaire, 1-5)	23	4.10	0.79
Friendliness (Questionnaire, 1-5)	23	3.57	1.24
Ability to calm down (Questionnaire, 1-5)	23	4.30	1.11
Stress in the police car (Questionnaire, 1-5)	23	2.95	1.63
Sudden aggression (Questionnaire, 1-5)	21	2.00	1.21

548 **Fig 1.** a) Non-transparent (learning phase) and b) transparent cylinder (test phase) measuring
549 inhibitory control, and the testers position during in the task, c) V-detour and d) closed impossible
550 task box, at the second phase of the test.

551 **Fig 2.** Scatter plot showing the association between cylinder task success (%), which measures self-
552 control, and the number of explosives detected by the dogs during the search task (N= 22, two dots
553 are overlapping with other dots).

554