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

Katriina Tiira[1,2], Antti Tikkanen[3] & Outi Vainio[2]

[1]SmartDOG, Pietilänkatu 5, 11130 Riihimäki, Finland

[2]Department of Equine and Small Animal Medicine, P.O. Box 57, FI-00014 University of Helsinki, Finland

[3]Police Dog Training Centre, Koirakoulunkatu, FI-13130 Hämeenlinna, Finland

Corresponding author: Katriina Tiira, Katriina.tiira@helsinki.fi

Keywords: cognition, dog, inhibitory control, motor inhibition, explosive detection, working dog

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,

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

Introduction

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

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

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

In addition to good inhibitory control, traits most likely important for an explosive search dog are the ability to work and solve problems independently and persistently. However, the dog also needs 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

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

Behavioural test

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

Behavioural test - Cylinder task

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

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

Behavioural test - V-detour

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

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

Behavioural test - Impossible task

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

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.

Success in the cylinder task was the only factor that was significantly associated with success in the explosive search task. Dogs that had a high success rate in explosive detection had fewer errors in the cylinder task compared to dogs with a low success rate (Spearman's correlation coefficient r_s = 0.466, P = 0.033, N = 22, Fig. 2). The percentage that each dog spent on using different problem-solving strategies (independent P = 0.463; human-dependent P = 0.975; abandoning the task, giving up P = 0.556, N = 17), was not associated with the search task success. The search task success was not associated with the time taken to solve the V-detour (P = 0,681) either. The handler's assessment of the dog's general working abilities (persistence P = 0.80, giving up P = 0.945, controllable P = 0.846, asking for help P = 0.059) was not associated with success in explosive searching. However, the number of errors (false positives) in the explosive search task was associated with the handler's evaluation on the dog's persistence (r_s = 0.460, P = 0.030, N = 23), where dogs evaluated by their handlers as more persistent also made more errors in the explosive search task. Everyday routine variables (amount of training P = 0.419, daily exercise P = 0.853) or age (P = 0.151) were not associated with success in the search task.

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

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

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

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

Acknowledgements

We are most grateful for all the police dog handlers who participated in this study. This work was financially supported by the Police Dog Training Centre.

Ethical approval

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

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

Declaration of interest

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

References

Baer, J., Schreck, M., Althoff, R.R., Rettew, D., Harder, V., Ayer, L., Albaugh, M., Crehan, E., Kuny-Slock, A., Hudziak, J.J., 2015. Child Temperament, Maternal Parenting Behavior, and Child Social Functioning. Journal of Child and Family Studies 24, 1152-1162 doi: 10.1007/s10826-014-9924-5.

Benjamini, Y., 1995. Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. Journal of the Royal Statistical Society.Series B (Methodological) 57, 289-300.

Brady, K., Cracknell, N., Zulch, H., Mills, D.S., 2018. Factors associated with long-term success in working police dogs. Appl. Anim. Behav. Sci. 207, 67-72 doi: 10.1016/j.applanim.2018.07.003.

Bray, E., MacLean, E., Hare, B., 2015. Increasing arousal enhances inhibitory control in calm but not excitable dogs. Anim Cogn 18, 1317-1329 doi: 10.1007/s10071-015-0901-1.

431 Bray, E., MacLean, E., Hare, B., 2014. Context specificity of inhibitory control in dogs. Anim Cogn
432 17, 15-31 doi: 10.1007/s10071-013-0633-z.

433 Bray, E., Sammel, M., Seyfarth, R., Serpell, J., Cheney, D., 2017. Temperament and problem solving
434 in a population of adolescent guide dogs. Anim. Cogn. 20, 923-939 doi: 10.1007/s10071-017-1112-
435 8 [doi].

436 Brucks, D., Marshall-Pescini, S., Wallis, L.J., Huber, L., Range, F., 2017. Measures of Dogs' Inhibitory
437 Control Abilities Do Not Correlate across Tasks. Frontiers in Psychology 8 doi:
438 10.3389/fpsyg.2017.00849.

439 Caspi, A., Roberts, B.W., Shiner, R.L., 2005. Personality development: stability and change. Annual
440 review of psychology 56, 453-484 doi: 10.1146/annurev.psych.55.090902.141913.

441 Cook, P.F., Prichard, A., Spivak, M., Berns, G.S., 2016. Awake canine fMRI predicts dogs' preference
442 for praise vs food. Social cognitive and affective neuroscience 11, 1853.

443 Corr, P., 2010. Individual Differences in Cognition: in Search of a General Model of Behaviour
444 Control, in: Anonymous Handbook of Individual Differences in Cognition. First ed. Springer New
445 York, New York, NY, pp. 3-26.

446 Dalal, S., Hall, N.J., 2019. Behavioral Persistence is Associated with Poorer Olfactory Discrimination
447 Learning in Domestic Dogs. Behav. Processes , 64-71.

448 Diergaarde, L., 2008. Impulsive Choice and Impulsive Action Predict Vulnerability to Distinct Stages
449 of Nicotine Seeking in Rats. Biol. Psychiatry 63, 301-308.

450 Duckworth, A., Seligman, M., 2017. The Science and Practice of Self-Control. Perspectives on
451 Psychological Science 12, 715-718 doi: 10.1177/1745691617690880.

452 Duckworth, A., 2015. The significance of self-control. PNAS 108, 2639-2640 doi:
453 10.1073/pnas.1019725108.

454 Duckworth, A.L., Kern, M.L., 2011. A meta-analysis of the convergent validity of self-control
455 measures. Journal of Research in Personality 45, 259-268 doi: 10.1016/j.jrp.2011.02.004.

456 Ennik, I., Liinamo, A., Leighton, E., van Arendonk, J., 2006. Suitability for field service in 4 breeds of
457 guide dogs. Journal of Veterinary Behavior: Clinical Applications and Research 1, 67-74 doi:
458 10.1016/j.jveb.2006.06.004.

459 Fadel, F.R., Driscoll, P., Pilot, M., Wright, H., Zulch, H., Mills, D., 2016. Differences in Trait
460 Impulsivity Indicate Diversification of Dog Breeds into Working and Show Lines. Scientific reports
461 6, 22162 doi: 10.1038/srep22162.

462 Foyer, P., Bjällerhag, N., Wilsson, E., Jensen, P., 2014. Behaviour and experiences of dogs during
463 the first year of life predict the outcome in a later temperament test. Appl. Anim. Behav. Sci. 155,
464 93-100 doi: 10.1016/j.applanim.2014.03.006.

465 Gerencser, L., Bunford, N., Moesta, A., Miklosi, A., 2018. Development and validation of the
466 Canine Reward Responsiveness Scale -Examining individual differences in reward responsiveness
467 of the domestic dog. Sci. Rep. 8, 1 doi: 10.1038/s41598-018-22605-1 [doi].

468 Glady, Y., Genty, É, Roeder, J., 2012. Brown Lemurs (Eulemur fulvus) Can Master the Qualitative
469 Version of the Reverse-Reward Contingency. PLoS One 7, e48378 doi:
470 10.1371/journal.pone.0048378.

471 Griffin, A.S., Guillette, L.M., Healy, S.D., 2015. Cognition and personality: an analysis of an
472 emerging field. Trends in ecology & evolution 30, 207-214 doi: 10.1016/j.tree.2015.01.012.

473 Jenkins, E.K., Dechant, M.T., Perry, E.B., 2018. When the Nose Doesn't Know: Canine Olfactory
474 Function Associated With Health, Management, and Potential Links to Microbiota. Frontiers in
475 Veterinary Science 5, 56.

476 MacLean, E., Hare, B., 2018. Enhanced Selection of Assistance and Explosive Detection Dogs Using
477 Cognitive Measures. Frontiers in Veterinary Science 5.

478 Maclean, E., Hare, B., Nunn, C.L., Addessi, E., Amici, F., Anderson, R.C., Aureli, F., Baker, J.M.,
479 Bania, A.E., Barnard, A.M., Boogert, N.J., Brannon, E.M., Bray, E.E., Bray, J., Brent, L.J.N., Burkart,
480 J.M., Call, J., Cantlon, J.F., Cheke, L.G., Clayton, N.S., Delgado, M.M., Divincenti, L.J., Fujita, K.,
481 Herrmann, E., Hiramatsu, C., Jacobs, L.F., Jordan, K.E., Laude, J.R., Leimgruber, K.L., Messer, E.J.E.,
482 Moura, Antonio C De A, Ostojić, L., Picard, A., Platt, M.L., Plotnik, J.M., Range, F., Reader, S.M.,
483 Reddy, R.B., Sandel, A.A., Santos, L.R., Schumann, K., Seed, A.M., Sewall, K.B., Shaw, R.C.,
484 Slocombe, K.E., Su, Y., Takimoto, A., Tan, J., Tao, R., Van Schaik, C.P., Virányi, Z., Visalberghi, E.,
485 Wade, J.C., Watanabe, A., Widness, J., Young, J.K., Zentall, T.R., Zhao, Y., 2014. The evolution of
486 self-control. Proceedings of the National Academy of Sciences 111, E2148 doi:
487 10.1073/pnas.1323533111.

488 Marshall-Pescini, S., Rao, A., Virányi, Z., Range, F., 2017. The role of domestication and experience
489 in 'looking back' towards humans in an unsolvable task. Scientific Reports (Nature Publisher
490 Group) 7, 46636 doi: 10.1038/srep46636.

491 Marshall-Pescini, S., Virányi, Z., Range, F., 2015. The effect of domestication on inhibitory control:
492 wolves and dogs compared. PLoS ONE 10, e0118469. doi:10.1371/journal.pone.0118469.

493 Mayack, C., Naug, D., 2015. Starving honeybees lose self-control. Research .

494 Miklósi, Á, Kubinyi, E., Topál, J., Gácsi, M., Virányi, Z., Csányi, V., 2003. A Simple Reason for a Big
495 Difference:Wolves Do Not Look Back at Humans, but Dogs Do. Current Biology 13, 763-766 doi:
496 10.1016/S0960-9822(03)00263-X.

497 Moffitt, T.E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R.J., Harrington, H., Houts, R., Poulton,
498 R., Roberts, B.W., Ross, S., Sears, M.R., Thomson, W.M., Caspi, A., 2011. A gradient of childhood
499 self-control predicts health, wealth, and public safety. Proc. Natl. Acad. Sci. U. S. A. 108, 2693.

500 Müller, C., Riemer, S., Viranyi, Z., Huber, L., Ranhe, F., 2015. Inhibitory Control, but Not Prolonged
501 Object Related Experience Appears to Affect Physical Problem Solving Performance of Pet
502 Dogs2016.

503 Passalacua, S., Marshall-Pescini, S., Merola, I., Palestrini, C., Prato Previde, E., 2013. Different
504 problem-solving strategies in dogs diagnosed with anxiety-related disorders and control dogs in an
505 unsolvable task paradigm. Applied Animal Behaviour Science 147, 139-148.

506 Persson, M., Roth, L., Johnsson, M., Wright, D., Jensen, P., 2015. Human-directed social behaviour
507 in dogs shows significant heritability. Genes, Brain and Behavior 14, 337-344 doi:
508 10.1111/gbb.12194.

509 Persson, M., Wright, D., Roth, L., Batakis, P., Jensen, P., 2016. Genomic Regions Associated With
510 Interspecies Communication in Dogs Contain Genes Related to Human Social Disorders. Scientific
511 Reports 6, 33439 doi: 10.1038/srep33439.

512 Pongrácz, P., 2001. Social learning in dogs: the effect of a human demonstrator on the
513 performance of dogs in a detour task. Anim. Behav. 62, 1109-1117.

514 Riemer, S., Mills, D., Wright, H., 2014. Impulsive for life? The nature of long-term impulsivity in
515 domestic dogs. Anim Cogn 17, 815-819 doi: 10.1007/s10071-013-0701-4.

516 Roberts, W., Fillmore, M.T., Milich, R., 2011. Linking impulsivity and inhibitory control using
517 manual and oculomotor response inhibition tasks. Acta Psychologica 138, 419-428 doi:
518 10.1016/j.actpsy.2011.09.002.

519 Sinn, D.L., Gosling, S.D., Hilliard, S., 2010. Personality and performance in military working dogs:
520 Reliability and predictive validity of behavioral tests. Applied Animal Behaviour Science 127, 51-65
521 doi: 10.1016/j.applanim.2010.08.007.

522 Svartberg, K., 2006. Breed-typical behaviour in dogs—Historical remnants or recent constructs?
523 Appl. Anim. Behav. Sci. 96, 293-313.

524 Tiira, K., Lohi, H., 2014. Reliability and validity of a questionnaire survey in canine anxiety research.
525 Appl. Anim. Behav. Sci. 155.

526 Tomkins, L.M., Thomson, P.C., McGreevy, P.D., 2011. Behavioral and physiological predictors of
527 guide dog success. Journal of Veterinary Behavior: Clinical Applications and Research 6, 178-187
528 doi: 10.1016/j.jveb.2010.12.002.

529 Verbruggen, F., 2009. Models of response inhibition in the stop-signal and stop-change paradigms.
530 Neurosci. Biobehav. Rev. 33, 647-661.

531 Vernouillet, A., Stiles, L., Andrew McCausland, J., Kelly, D., 2018. Individual performance across
532 motoric self-regulation tasks are not correlated for pet dogs. Learning & Behavior 46, 522-536 doi:
533 10.3758/s13420-018-0354-x.

534 Wilsson, E., Sundgren, P., 1998. Behaviour test for eight-week old puppies—heritabilities of tested
535 behaviour traits and its correspondence to later behaviour. Applied Animal Behaviour Science 58,
536 151-162 doi: 10.1016/S0168-1591(97)00093-2.

537 Wright, H.F., Mills, D.S., Pollux, P.M.J., 2011. Development and Validation of a Psychometric Tool
538 forAssessing Impulsivity in the Domestic Dog (Canis familiaris). Int J Comp Psychol 24, 210-225.

539 Wright, H.F., Mills, D.S., Pollux, P.M.J., 2012. Behavioural and physiological correlates of impulsivity
540 in the domestic dog (Canis familiaris). Physiology & Behavior 105, 676-682 doi:
541 10.1016/j.physbeh.2011.09.019.

542

543 **Table 1**. Descriptive statistics (sample size, mean and standard deviation) of the variables in explosive
544 qualification task, behavioural test and questionnaire.
545

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

546
547

548 **Fig 1**. a) Non-transparrent (learning phase) and b) transparrent 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