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COMPARATIVE COGNITION & BEHAVIOR REVIEWS

The Future of Detector Dog Research

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Troisi et al. thoroughly review the range of cognitive and behavioral factors that can influence detection dog performance. In this commentary, we focus on the industry goal of identifying dogs with the highest chance of a successful working career. We propose a bio-behavioral approach involving systematically identifying functional relations between variables related to success within working dog populations. We suggest developing an endophenotype for identifying the factors related to success and discuss related implications and challenges.

Keywords: *canine cognition*, *detection dogs*, *canine fMRI*

Troisi et al.'s (2019) target article provides a thorough and timely review of the various cognitive and behavioral aspects of detection dog performance. With rising demands for explosives detection dogs, as well as recent innovations in the specialization of scent detection dogs for nontraditional applications like ecological conservation or disease detection, refining the practices of training and using scent detection dogs is imperative. The breadth of the review underscores the constellation of factors that affect the success of detection dogs and the importance of considering how they interact as a system rather than in isolation.

One point raised by the authors cannot be emphasized enough: the importance of synergy between the scientific and professional working dog communities. Studying the underlying factors that influence performance from an empirical perspective, borrowing from theory and methodologies of comparative cognition and behavioral sciences, can offer an important objective approach. However, working dog professionals should be consulted in the development of research questions and experimental design to determine ecological validity and practical relevance. Bridging the gap between the scientific and professional communities will be critical for consistency in terminology and measurement and for the application of important discoveries. A related but separate issue should also be considered: cultural differences with regard to the use of working dogs, which can affect practical considerations in addressing many of the points raised in the review. For example, Troisi et al. (2019) highlight the importance of optimizing housing, general management, and training approaches for working success on the premise that stress can greatly affect learning and performance. However, an alternative viewpoint is to optimize the selection of candidates that are resilient to practical constraints on available housing solutions or cultural differences in training methodologies.

Troisi et al.'s (2019) comprehensive theoretical framework provides a road map for critically needed research regarding the selection and preparation of working dogs. Although no one review can be exhaustive, several phenomena are addressed, such as motivation, search persistence, and vigilance, for which the behavioral economic context and related principles derived from signal detection theory can serve as important

considerations in past and future research (Gadbois & Reeve, 2016; Hall, 2017; Porritt et al., 2015).

In this commentary, we focus on the industry goal of developing the ideal dog with a high chance of completing training and achieving a prosperous career. Troisi et al. (2019) provide a thorough review of individual differences in behavioral characteristics that can influence success as a detection dog, including motivation, fearfulness, and resilience, among others. These traits are consistently acknowledged as critical in the selection of successful detection dogs, but the challenge lies in their reliable identification. We agree with two points raised by the authors: (a) It is difficult to determine which traits, and to what extent the traits, are affected by experience and training rather than the result of genetic selection, and (b) focusing on the identification of the biological bases of such underlying characteristics presents a promising approach. The first is at the crux of challenges faced by attempting to develop reliable tests predictive of future behavior, which may be enhanced by the second. Identifying underlying biological mechanisms will allow for the quantification of traditionally subjective measures and for assessments of the effects of environmental factors. Until reliable indicators of success can be identified, and their corresponding stability and genetic basis determined, advances in working dog selection will be limited.

Developing an endophenotype can provide a robust, biologically based framework for characterizing working dog suitability. The value of traditional behavioral assessments is not overlooked; rather, their use in conjunction with concurrent measures will enhance their utility. For example, we recently published an examination of the behavioral characteristics related to success in a particular population of specialized explosives detection dogs (Lazarowski et al., 2018). Although we were able to identify a number of traits associated with success, the subjective nature of the assessments used to evaluate behavioral characteristics limits early predictability and overall generalizability.

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One approach is functional magnetic resonance imaging (fMRI), a noninvasive in vivo method for identifying neural activity associated with emotional states or behavior. A major deterrent to fMRI use in veterinary medicine is the need to anesthetize or restrain animals for immobilization, which alters state of consciousness and/or emotional states and thus the validity of the scan (Vermeire et al., 2011), but recent innovations in training dogs to lie motionless and awake during fMRI scans have allowed for significant advancements in neuroimaging research with dogs (Thompkins, Deshpande, Waggoner, & Katz, 2016). As a critical first step, Jia et al. (2014) demonstrated the importance of scanning awake versus anesthetized dogs for fMRI research, showing parametric modulation of odor concentration in brain activation in addition to activation in the frontal cortex (an area likely to be involved in diverse cognitive processes, as it is in primates) of awake dogs. A study by Berns, Brooks, Spivak, and Levy (2017) found that activation of brain areas related to motivation and arousal (i.e., caudate and amygdala) were predictive of suitability in dogs training to become assistance dogs. The authors argued that such activation may be indicative of internal states that would not be apparent from behavioral observations alone. Although particular phenotypic profiles vary between dogs suited for different working tasks, and may even vary within dogs trained for detection work depending on the nature of the target, the reinforcer used, and the environment in which the dog must work, motivation and arousal are considered universally important to all working dogs. A term such as *drive*, referring to the dogs' intrinsic motivation to work, is widely recognized as an important factor in working dog success but equally scrutinized for its difficulty to operationalize and reliably measure. Similarly, arousal may reflect either excitement or anxiety (Berns et al., 2017). Identifying the biological mechanisms underpinning motivational drives and arousal, including reinforcement sensitivity as suggested by Troisi et al. (2019), may be valuable in refining definitions and assessments of problematic terms used in the industry.

Troisi et al.'s (2019) discussion of arousal and its influence on performance and welfare highlights an important topic that has received little attention, especially in regards to detection dogs. The authors focus most of their discussion on how arousal influences performance in the context of learning and memory impairment or enhancement, but the effects of arousal are likely applicable to other areas as well. Similarly, though arousal here is largely considered in the context of distress and

negative emotional arousal, equally adverse effects may result from arousal in the form of positively valenced emotion, that is, excitement. This may be particularly relevant to detection dogs, as the industry has traditionally favored bold, excitable, high-energy dogs. This behavioral profile tends to be emphasized in order to select dogs capable of working over long periods in strenuous conditions in exchange for their (eventual) desired reward. Therefore, dogs more motivated to work for their reward and playfully interact with the handler are preferred. However, little consideration has been given to how such excitability may interfere with performance in detection dogs. For example, Troisi et al. discuss a recent study that found that pet dogs had higher baseline arousal levels than assistance dogs and that increasing arousal enhanced assistance dog performance but impaired pet dog performance (Bray, MacLean, & Hare, 2014). It is likely that through selection, dogs bred and trained for detection work have higher baseline levels of arousal than other types of working dogs and pets. In situations that the dogs perceive as exciting, such as anticipating going to work or engaging in a search, arousal levels may interfere with performance. Indeed, panting (a sign of arousal) has been shown to interfere with detection dogs' ability to sniff (Gazit & Terkel, 2003). Selecting a dog ideally suited for detection work should take into account the dog's baseline arousal as well as arousal in different contexts and in response to different stimuli. More research is needed to determine the optimal level of arousal, whether arousal in one context is associated with arousal in others (which would thus be indicative of state-level arousal rather than trait) and how arousal in one context translates to working potential. For example, stereotypic behaviors (e.g., spinning, wall bouncing) displayed in the kennel environment are commonly observed in working dogs (Cao et al., 2014), but little is known about the factors that lead to their development and what it means for the dog's performance. Stereotypy is often seen as a sign of impaired welfare in captive animals, but how such behaviors are related to arousal are unclear. It is possible that for kenneled working dogs, environmental triggers such as stimuli predictive of going to work lead to increased arousal levels. Stereotypic behaviors may then be manifestations of increased arousal, with individual dogs developing different patterns of coping with the increased arousal. Why some individuals develop such stereotypies whereas others reared and housed in the same environment do not, and whether such behavior is associated with arousal in other contexts, merits further study. Understanding the biological mechanisms of arousal and differentiating between positive and negative arousal through physiological measures such as heart rate variability or cortisol levels, for example, will be important for answering such questions. Although distress and excitement may look the same physiologically, triangulating physiological, behavioral, and neurological measures to determine emotional valence and arousal level will allow for an even more robust understanding.

A bio-behavioral approach to understanding the mechanisms of detection dog performance presents some challenges. Before reliable predictions can be made, a large number of data points will be needed, including replication within and across research programs. Obtaining a large sample size while minimizing variability in breed, housing environment, and other extraneous factors will be important. Training dogs to lie still for awake and unrestrained fMRI is a challenge in itself, though a few research groups have had success using various methods. However, applying fMRI methods to high-energy, easily aroused dogs like detection dogs presents a unique challenge. When selecting dogs for fMRI studies, researchers typically screen for dogs with calm temperaments that are amenable to learning to lie still for long periods (Berns & Cook, 2016). When investigating individual differences in cognitive processes using such methods, researchers should be aware of selection biases that may be introduced when certain behavioral criteria are used.

To be sure, Troisi et al. (2019) are spot-on when they stress the importance of systematic evaluation in understanding phenomena underlying working dog success. To this we would add that the optimal approach would involve systematic variation of the appropriate variables to reveal functional relations that may be general or specific within working dog populations. Testing and understanding different phenomena at developmental time points will also be crucial for early selection of working dogs, and assessing their longevity over time will be equally important. It is important to keep in mind that currently there is no technology that can outperform a successful detector dog. Although the journey to develop an accurate endophenotype will be arduous, the payoff will no doubt be transformational.

References

Berns, G. S., Brooks, A. M., Spivak, M., & Levy, K. (2017). Functional MRI in awake dogs predicts suitability for assistance work. *Scientific Reports*, *7*, 43704. doi:10.1038/srep43704

Berns, G. S., & Cook, P. F. (2016). Why did the dog walk into the MRI? *Current Directions in Psychological Science*, *25*, 363–369. doi:10.1177/0963721416665006

Bray, E. E., MacLean, E. L., & Hare, B. A. (2014). Context specificity of inhibitory control in dogs. *Animal Cognition*, *17*, 15–31. doi:10.1007/s10071-013-0633-z

Cao, X., Irwin, D. M., Liu, Y. H., Cheng, L. G., Wang, L., Wang, G. D., & Zhang, Y. P. (2014). Balancing selection on CDH2 may be related to the behavioral features of the Belgian malinois. *PLoS ONE*, *9*(10), 1–7. doi:10.1371/journal.pone.0110075

Gadbois, S., & Reeve, C. (2016). The semiotic canine: Scent processing dogs as research assistants in biomedical and environmental research. *Dog Behaviour*, *2*(3), 26–32. doi:10.4454/db.v2i3.43

Gazit, I., & Terkel, J. (2003). Explosives detection by sniffer dogs following strenuous physical activity. *Applied Animal Behaviour Science*, *81*, 149–161. doi:10.1016/S0168-1591(02)00274-5

Hall, N. J. (2017). Persistence and resistance to extinction in the domestic dog: Basic research and applications to canine training. *Behavioural Processes, 141*, 67–74. doi:10.1016/j.beproc.2017.04.001

Jia, H., Pustovyy, O. M., Waggoner, P., Beyers, R. J., Schumacher, J., Wildey, C., … Vodyanoy, V. J. (2014). Functional MRI of the olfactory system in conscious dogs. *PLoS ONE*, *9*(1). doi:10.1371/journal.pone.0086362

Lazarowski, L., Haney, P. S., Brock, J., Fischer, T., Rogers, B., Angle, C., … Waggoner, L. P. (2018). Investigation of the behavioral characteristics of dogs purpose-bred and prepared to perform Vapor Wake® detection of person-borne explosives. *Frontiers in Veterinary Science*, *5*, 50. doi:10.3389/fvets.2018.00050

Porritt, F., Shapiro, M., Waggoner, P., Mitchell, E., Thomson, T., Nicklin, S., & Kacelnik, A. (2015). Performance decline by search dogs in repetitive tasks, and mitigation strategies. *Applied Animal Behaviour Science*, *166*, 112–122. doi:10.1016/j.applanim.2015.02.013

Thompkins, A. M., Deshpande, G., Waggoner, P., & Katz, J. S. (2016). Functional magnetic resonance imaging of the domestic dog: Research, methodology, and conceptual issues. *Comparative Cognition & Behavior Reviews*, *11*, 63–82. doi:10.3819/ccbr.2016.110004

Troisi, C., Mills, D., Wilkinson, A., & Zulch, H. (2019). Behavioral and cognitive factors that affect the success of scent detection dogs. *Comparative Cognition & Behavior Reviews*, *14*, 51–76. doi:10.3819/CCBR.2019.140006

Vermeire, S., Audenaert, K., Vandermeulen, E., De Meester, R., Van Bree, H., Dobbeleir, A., & Peremans, K. (2011). What's in a brain: Neuroanatomy and neurochemistry of anxiety disorders in dogs. *Vlaams Diergeneeskundig Tijdschrift*, *80*, 175–184