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Reward Type Affects Dogs' Performance in the Cylinder Task

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Abstract – The cylinder task, which requires detouring around an obstacle to retrieve a reward, is a popular method for assessing inhibitory control in dogs and other species. However, performance on the cylinder task has poor construct validity represented by its lack of correlations with other inhibitory control measures, ceiling effects, and influence of non-cognitive factors. In the current study we examined whether reward type affected dogs' performance in the cylinder task. We compared working-line Labrador retrievers' (n = 38) performance on two conditions of the cylinder task, one with a treat and another with a ball reward, and found that dogs performed significantly better when a treat was used. Our secondary goal was to determine if how we defined a dog's response changed interpretation of the results. We found better performance when a narrower definition of an inhibitory control failure was used. Further, under one condition of reward type and response definition, cylinder task performance was predicted by another measure of inhibitory control (Dog Impulsivity Assessment Scale scores). These findings are the first to show the effect of reward type on cylinder task performance as well as a relationship between the cylinder task and another measure of inhibitory control in dogs. We discuss these results in relation to previous findings on the effects of task features on cylinder task performance and its construct validity.

Keywords – Cylinder task, Detour task, Dog, Reward type

Detour tasks are commonly used to measure inhibitory control, or the ability to suppress an impulsive response in favor of one that is more productive. In a typical detour task, a reward is presented behind an obstacle, requiring inhibition of a direct approach in favor of a detour around the side (Kabadayi et al., 2018). For example, in the "cylinder task," a reward is placed in the center of a transparent cylinder and can only be accessed through openings on either end. The cylinder task has been adapted to a wide range of species in order to evaluate phylogenetic and ontogenetic mechanisms of inhibitory control (Kabadayi, Jacobs et al., 2017; Maclean et al., 2014). In dogs, the cylinder task has become an increasingly popular method for assessing subject characteristics influencing inhibitory control (Foraita et al., 2021), demonstrating sensitivity to temperament (Bray et al., 2015), development (Lazarowski, Krichbaum et al., 2020), domestication status (Marshall-Pescini et al., 2015), sex (Junttila et al., 2021), and working ability (Tiira et al., 2020).

Some findings have indicated that non-cognitive features can influence performance on detour tasks, such as the type, visibility, and distance of the reward (see Kabadayi et al., 2018, for review), contributing to ongoing questions regarding their validity as a measure of inhibitory control (van Horik et al., 2018). Further, several studies have failed to find correlations between performance on the cylinder task and other measures of inhibitory control in dogs (Bray et al., 2014; Brucks, Marshall-Pescini et al., 2017; Fagnani et al., 2016; Kelly et al., 2019; Lazarowski, Krichbaum et al., 2020; Marshall-Pescini et al., 2015; Vernouillet et al., 2018). Previous studies have reported within-session learning and ceiling effects in cylinder task performance in several species, suggesting that the task may be too easy, which may be the reason for a lack of correlations with other inhibitory control measures (Fagnani et al., 2016; Kabadayi, Krasheninnikova et al., 2017; Marshall-Pescini et al., 2015; Vernouillet et al., 2016, 2018).

In contrast to reported ceiling effects, we recently reported average cylinder task performance by adult detection dogs of 65% (Lazarowski, Krichbaum et al., 2020), which was notably lower than the high accuracies reported for dogs in other studies. One possible reason for this difference is the temperament of the populations tested. Detection dogs are bred for high energy and strong motivational drives, resulting in higher impulsivity and arousal compared to calmer and more docile temperaments of dogs bred for service and assistance roles (Bray, Otto et al., 2021; Fadel et al., 2016). Indeed, Bray et al. (2015) demonstrated differences in detour task performance between pet and service dogs, with experimentally-induced arousal differentially affecting performance on the task as a function of group differences in baseline arousal. That is, increasing arousal improved performance for dogs with lower baseline arousal levels, but impaired performance for dogs with high baseline arousal levels. Subject characteristics, such as physiological state (e.g., hunger; Shaw, 2017) or species differences in intragroup food competition (Vlamings et al., 2010), may also dictate the appeal of the reward and, subsequently, inhibitory control (Kabadayi et al., 2018). In our previous study, the population consisted of working line Labrador retrievers selected for strong object-play motivation (Lazarowski, Waggoner et al., 2020). Thus, it is possible that for this population, the reward used (a ball) led to increased arousal and reduced inhibitory control. Indeed, studies have shown that dogs behave more impulsively when a more highly preferred reward is used (Brucks, Soliani et al., 2017). The majority of dog cylinder task studies have used food as the reward, except for Vernouillet et al. (2018) who used the dogs' owner-reported preferred reward between food and a toy, and Maclean & Hare (2018) who used a food and a toy for all dogs. However, though reward type has been suggested as a potential factor influencing cylinder task performance in dogs, leading to discrepancies across studies (Marshall-Pescini et al., 2015), it has not yet been systematically examined.

Other potential issues with the cylinder task are demonstrated by analyses of failure patterns, revealing differences in the types of errors committed which may influence interpretation of the results. According to Kabadayi, Krasheninnikova et al. (2017), the traditional definition for an incorrect response in the cylinder task, which considers any contact with the surface of the exterior as incorrect, may result in false negatives if the animal touches the cylinder through exploration or by accident (i.e., bumping into the edge of the cylinder while detouring). Instead, true failures of inhibition may be better represented by touches that occur to the center of the cylinder, towards the location of the reward. When only counting errors in which the touch was directed towards the reward, parrots performed significantly better overall, with species differences in the types of errors committed. Error patterns have not been examined in cylinder task studies with dogs, which have exclusively used the more conservative definition of a correct response (i.e., touching any part of the cylinder's exterior results in an error). Therefore, coding errors using a definition that more accurately reflect inhibition failures may reveal insights into the validity of the task.

The aim of the current study was to determine whether methodological aspects of the cylinder task, namely reward type and response definition, influenced dogs' performance. We first performed a preference test between a ball and treat to determine the strength of dogs' preference for the two types of rewards. We expected that for this population of dogs selected for high levels of prey and play drives (Lazarowski, Waggoner et al., 2020), the ball would represent a highly valued reward leading to increased arousal. We also expected treats to be appealing given the strong food motivation of Labrador retrievers (Raffan et al., 2016), but less arousal-inducing than the ball. Using a within-subjects design, we tested dogs on the cylinder task using both rewards in separate blocks. We predicted that dogs, such as those tested in our previous study (i.e., Labrador retrievers from a working dog population demonstrating high ball-drive), would perform better when tested with a treat compared to a ball reward, and that dogs that more highly preferred the treat would perform better compared to dogs that more highly preferred the ball, due to potential high arousal induced by the ball. In addition, we compared responses according to the typical definition versus a revised definition. We hypothesized that a definition more precisely capturing reward-directed responses would better reflect inhibitory control failures rather than errors that might be due to non-cognitive factors, which could have contributed to the poorer performance by this population of dogs in our previous study. Additionally, we compared cylinder task performance to data derived from a validated assessment of inhibitory control (Dog Impulsivity Assessment Scale; Wright et al., 2011) to further examine the validity of the task.

Methods

Ethics Statement

Ethical approval was granted by the Auburn University Institutional Care and Use Committee (protocol #2020-3730).

Subjects

Subjects were adult Labrador retrievers (*N* = 39; 18 F (16 altered)/21 M (17 altered)) pertaining to the Auburn University Canine Performance Sciences (AUCPS) program, selectively bred and trained for detection tasks and regularly engaged in odor detection training and maintenance. While participating in this study, dogs were individually housed in a temperature-controlled facility in indoor kennel runs with free access to an outdoor enclosure. Runs were equipped with a resting platform, a chew toy, and free access to water. Dogs were fed Purina® Pro Plan Performance twice daily. No food or water deprivation occurred for this study. Monday-Friday, dogs received social enrichment through play and exercise with trainers and cohort mates, and additional physical, sensory, and occupational enrichment through reward-based odor discrimination training and environmental socialization as part of their training regimen.

Dogs in this study occasionally participated in cognitive and behavioral tasks for other studies, with similar levels of experience across the sample. Given findings that age influences inhibitory control (Bray et al., 2014; Bray, Gruen et al., 2021; Mongillo et al., 2013; Piotti, Szabó et al., 2018; Tapp et al., 2003; Van Bourg et al., 2021), we restricted our sample to dogs of mature adult age (range: 1.37-7.14 years, *M* = 4.00, *SEM* = 0.29).

Rewards

We selected a toy and a food treat as the two rewards in the study. The toy was a ChuckIt® ball (7.76 cm in diameter), the same as in our previous study (Lazarowski, Krichbaum et al., 2020), which is the reward primarily used in the dogs' routine training. The treats were Bil-Jac PBnanas® (single pieces of peanut butter flavored soft treats, approximately 2 cm in size).

A priori Motivation Test

To ensure dogs were motivated to perform a trial for both types of rewards, a motivation trial was conducted first in which either a treat or the ball, counterbalanced across dogs, was placed on a cart (approximately 40 x 40 x 35 cm) 2 m away from the dog's start point while the dog stood out of view in a holding area (3 m x 2 m) adjacent to the start point, enclosed by movable plywood panels. The handler escorted the dog to the start point and released the dog to obtain the item (defined as consuming the treat or picking up the ball). The dog was then moved back to the holding area while the experimenter set up the next trial. A second identical trial was then conducted with the remaining reward. The amount of time that the dog took to obtain the item on each trial was recorded, with the requirement that dogs obtain each reward within 15 seconds in order to participate in the study.

Preference Test

Immediately following the motivation test, dogs underwent a two-choice preference test between a treat and the ball. The experimenter placed each item on a cart, counterbalanced for side, equidistant (2 m) from the dog's start point and 20 cm apart. On each trial, the handler escorted the dog to the start point and released the dog to make a choice, defined as above. The dog was then moved to the holding area while the experimenter set up the next trial. The amount of time that the dog took to obtain an item on each trial was recorded, with the requirement that dogs obtain a reward within 15 seconds. Trials were repeated until the dog chose the same reward nine total times out of 12 consecutive trials, with a maximum of 24 trials.

Cylinder Task

Cylinder task testing was conducted on a separate day following the preference test. Testing occurred inside an enclosure created by movable panels in the same building as the motivation and preference tests. The enclosure had a .5 m opening at the center of the front wall to create an entryway. A transparent cylinder (approximately 20 x 20 cm) with openings on both ends was placed on the ground, attached to a wooden platform for stability, 2 m from the entrance. A small plastic tray in the center of the cylinder held the reward in place during the trial. On each trial, the experimenter stood behind the cylinder, facing the entrance. The handler positioned the dog in the entryway facing the cylinder.

Training trials were conducted first to ensure that dogs could perform the motor response required by the task. On these trials, a white cover was affixed to the inside of the cylinder making it opaque. The lesser-preferred reward was used during training trials. To minimize learning effects given the within-subjects design (Vernouillet et al., 2018), training trials were performed until the first correct response was made. To begin a trial, the experimenter called the dog's name, held up the reward saying 'look!' and then placed the reward in the center of the cylinder, always baiting from the experimenter's right side. After placing the reward in the cylinder and returning to a neutral standing position with her head down, the experimenter said 'ok', signaling to the handler to release the dog. A correct response was defined as obtaining the reward through either side opening without contacting the exterior of the cylinder with the nose or paws. The trial ended when the dog obtained the reward, and the next trial commenced after approximately 30 s. If the dog did not respond within 15 seconds, the trial was marked as a time-out and was repeated (which only occurred on five total trials). Dogs that did not meet the training criterion within 10 trials were excluded from testing.

Following training trials, the cover was removed, and dogs completed ten test trials with one of the two rewards (counterbalanced across dogs regardless of preference). Dogs were then returned to their crate for a rest period with access to water for approximately 30 minutes before returning to complete another block of 10 trials with the other reward.

Dog Impulsivity Assessment Scale

Dogs' primary trainers (i.e., had worked with the dog for a minimum of one month), who were not involved in the cylinder testing, scored dogs on the 18-item Dog Impulsivity Assessment Scale (DIAS; Wright et al., 2011), which contains three subscales: Behavioral Regulation (impulsive actions and thoughts), Aggression (aggressive behaviors), and Responsiveness (reactions to novel stimuli; Piotti, Satchell et al., 2018). Trainers rated dogs on the level to which these characteristics reflected their "general personality" on a 5-point Likert scale (1: strongly disagree, 5: strongly agree) and a mean score was calculated for each subscale as well as an overall DIAS score for each dog, such that higher scores represented higher impulsivity (Wright et al., 2011).

Scoring and Data Analysis

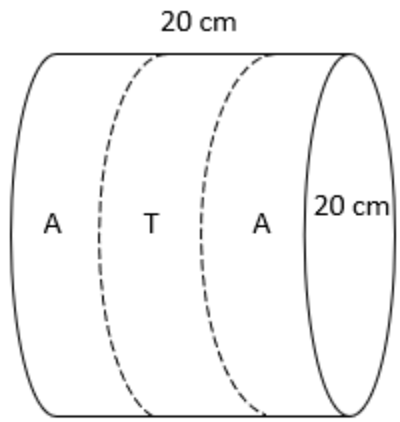
To examine effects of reward preference, we first computed a reward-preference index (RPI) for each dog using the number of trials the dog chose the ball (B) and treat (T) in the preference test, such that a score of 1.0 would represent exclusive ball choices while -1.0 would represent exclusive treat choices, using the following formula:

$$RPI = \frac{(B-T)}{(B+T)}$$

For test trials, we coded errors two different ways following the definitions by Kabadayi, Krasheninnikova et al. (2017) as errors made by either reaching towards the reward (any nose or paw contact with the cylinder that occurred within the middle third of the cylinder) or contact that occurred away from the reward (any nose or paw contact with the cylinder that occurred within the two outer thirds of the cylinder) (Figure 1). Therefore, we calculated two different accuracy scores (percentage of correct trials) for each dog using each definition: counting all touches as incorrect (*touch*) and counting only touches towards the middle third of the cylinder as incorrect (*towards*). Individual percentage of correct test trials for each dog was calculated for both rewards.

Figure 1

Cylinder Apparatus



Note. Schematic diagram of the cylinder apparatus showing the zones used for coding errors, in which errors were coded as towards (T) or away (A) from the reward.

We used generalized linear mixed models (GLMM), constructed and tested using the "lme4" package (Bates et al., 2015) in RStudio, to evaluate the effects of reward type (ball or treat), reward-preference index, condition order (first or second), sex, and the interactions between reward type, reward-preference index, and condition order on percent correct, using both the *touch* and *towards* definitions. Individual dog ID was included as a random effect. We removed non-significant interactions to find the minimal adequate model (Crawley, 2012). We visually inspected residual and fitted plots to assess linearity of independent variables and log odds and independence of observations. We used Cook's D, tested using the "influence.ME" package (Nieuwenhuis et al., 2012), to test for outliers (larger than 4 / (n - k (# of factors) -1)). To assess differences in performance when using different response criteria, we compared percent correct between definitions for each reward type using paired-sample t-tests (SPSS Version 25).

All trials were scored from video by an observer not blind to the study hypotheses. A subset of videos (20%) was scored by an additional observer, blind to the study hypotheses, to calculate inter-rater reliability. The inter-rater reliability was very good when using the *touch* definition (kappa = .87, $p < .001$), and moderate when using the *towards* definition (kappa = .73, $p < .001$).

Additionally, we ran an exploratory analysis to determine whether using a different response definition would reveal novel relationships between cylinder task performance and another measure of IC. We used GLMs, constructed and tested using the "lme4" package (Bates et al., 2015) in RStudio, to evaluate the predictability of DIAS scores (all subscales and overall DIAS), sex, and the interaction between DIAS scores and sex, on percent correct, using both the *touch* and *towards* definitions. These models were run separately for each reward type.

Results

A priori Motivation and Preference Tests

All dogs met the *a priori* motivation test criterion. Of the 39 dogs tested, 23 (59%) preferred the ball, 16 (41%) preferred the treat, and reward-preference index ranged from -1 to 1 (M = .29, SEM = .12).

Cylinder Task

One dog failed to meet the training criterion and was excluded from participating in test trials, with the remaining 38 dogs requiring an average of 1.61 trials to meet criterion (SEM = .22).

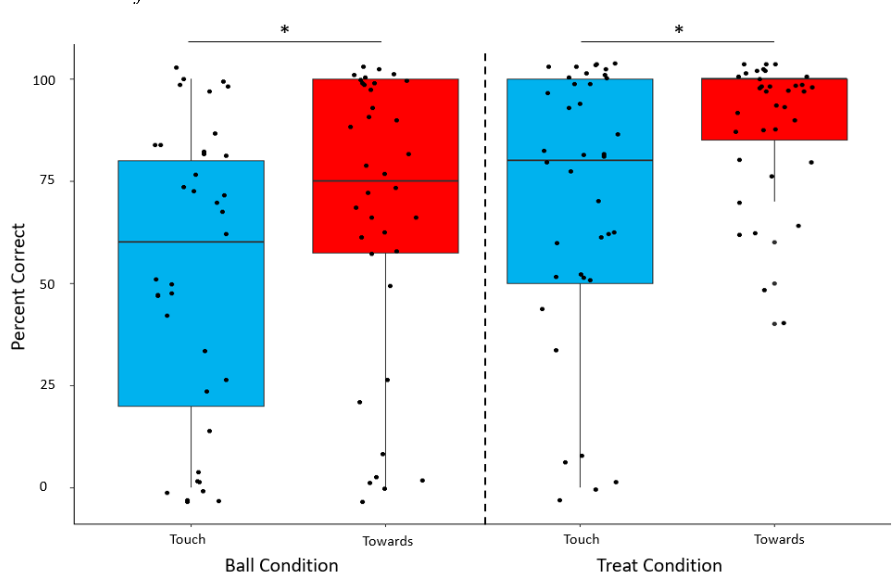
Using the typical *touch* response definition (i.e., counting all touches as incorrect), dogs performed better with the treat (M = 69.74; SEM = 5.33) than with the ball (M = 52.97; SEM = 5.95; GLMM: t = 2.8, p = .007), dogs that more strongly preferred the treat outperformed dogs that more strongly preferred the ball (GLMM: t = -2.56, p = .012), females outperformed males (GLMM: t = -2.78, p = .009), and performance was better on the second condition compared to the first (GLMM: t = 2.79, p = .009). There were no significant interactions (ps > .35). The assumption of linearity was met and there were no outliers.

Using the revised *towards* response definition (i.e., counting only touches made to the middle third of the cylinder as incorrect), dogs performed better with the treat (M = 88.86; SEM = 2.80) than with the ball (M = 66.67; SEM = 5.94; GLMM: t = 3.50, p = .002). There were no other significant main effects or interactions (ps > .05). The assumption of linearity was met and one dog that was determined an outlier was removed from the analysis as well as all subsequent analyses.

Figure 2 shows performance according to each response definition for each reward type. Performance was significantly higher when responses were scored using the *towards* definition compared to the *touch* definition for both reward types (ball condition: $t(35) = -4.57$, $p < .001$; treat condition: $t(34) = -4.13$, $p < .001$). For the ball condition comparison, the outlier found above and one dog that did not complete the ball condition were removed from the analysis. For the treat condition comparison, the outlier found above, and two dogs that were missing proper video footage were removed from the analysis.

Figure 2

Cylinder Task Performance

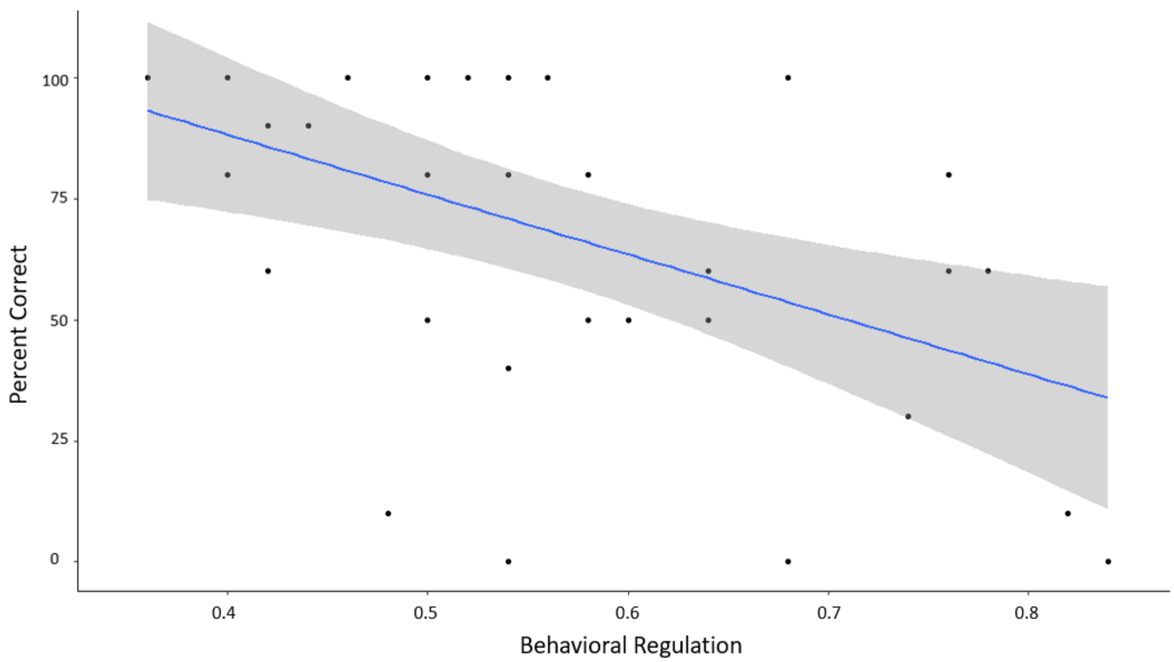


Note. Distribution of percent correct according to each response definition for both reward types. Horizontal lines represent medians, boxes represent the interquartile range, and whiskers represent the range of values within 1.5 X interquartile range. Dots are individual dogs, jittered to reduce over-plotting. Asterisks represent significant differences in performance ($p < .001$).

Due to the finding that cylinder task performance differed by reward type and response definition, we analyzed the relationship between the DIAS and cylinder task for the two reward types, for each definition, separately. We found that the Behavioral Regulation subscale of the DIAS significantly predicted cylinder task performance when using the treat reward and *touch* response definition (Figure 3; GLM: $t = -2.15$, $p = .038$). All other models were not significant (ps > .06).

Figure 3

Cylinder Task Performance as Predicted by the DIAS



Note. Overall cylinder task percent correct using the *touch* definition on the treat condition as a function of DIAS Behavioral Regulation subscale scores. The blue line illustrates the predicted linear trajectory with 95% confidence intervals.

Discussion

The current study examined whether reward type influenced dogs' performance in the cylinder task. As predicted, based on arousal effects of each reward type for this population, detection dogs performed better when solving the task for a treat rather than a ball. We also examined the effect of coding inhibition failures according to two different response definitions and found significantly better performance when a narrower definition of what constituted an inhibitory failure was used. Finally, we found that under one condition of reward type and response definition (i.e., treat reward and using the typical broader definition of an error), cylinder task performance was predicted by another measure of inhibitory control (i.e., Behavioral Regulation subscale of the DIAS). We discuss these results in relation to previous findings on the effects of methodological features on cylinder task performance and the validity of the cylinder task as a measure of inhibitory control in dogs.

We found that the majority of the dogs (59%) preferred the ball compared to the treat in the two-choice preference test. This result is not surprising given that the dogs tested were Labrador retrievers, a breed that exhibits pronounced object play (Mehrkam et al., 2017), and from a working population further selected for high levels of object play and possession (Lazarowski, Waggoner et al., 2020). However, regardless of reward preference, average performance in the treat condition (70%) was better than in the ball condition (53%) using the typical response definition and was similar to dogs' performance in a previous study that used treats with another population of detection dogs (67%; Tiira et al., 2020). Therefore, the lower cylinder task performance in our previous study (using different dogs from the same population) relative to the high accuracies commonly reported in other studies was likely due to an interaction between characteristics of our population and the use of a ball. Thus, we attribute the poorer performance in the ball condition to its arousing effect, in line with findings by Bray et al. (2015) demonstrating that arousal can influence dogs' performance on inhibitory control tasks. Our results indicate that even when arousal is not intentionally induced, as in the Bray et al. study, methodological features of the task can inadvertently influence arousal and, subsequently, performance. However, we did not quantify arousal during the task, therefore further research is needed to confirm that our observed effect of reward type was due to arousal.

We also found that dogs that strongly preferred the treat outperformed dogs that strongly preferred the ball overall, regardless of reward type used, but only when the typical error definition was used. We interpret this finding to suggest that dogs' reward preference reflects underlying temperament characteristics including baseline arousal. For example, strong ball/toy responsiveness in dogs has been linked to hyperactivity and impulsivity (Gerencsér et al., 2018); thus, ball-preferring dogs may exhibit naturally higher arousal levels than treat-preferring dogs. This finding only occurring for the *touch* definition may indicate that this definition more likely captures general arousal. Again, these results are in line with those by Bray et al. (2015) in which the effects of the experimentally induced arousal depended on the dogs' baseline arousal levels, which corresponded to specific phenotypic profiles. However, we did not include a measure of dogs' baseline level of arousal to confirm this.

In line with previous work (Juntilla et al., 2021), we also found that females outperformed males in the cylinder task. While the sex effect was found regardless of reward type used, it only occurred when the *touch* definition was used, which may also relate to arousal as we have previously found that male detection dogs score higher on measures of reward-related arousal (Lazarowski et al., 2021). We also found an order effect such that performance increased in the second condition, corroborating previous findings on learning effects for this task (van Horik et al., 2018). This effect occurred regardless of reward type but only when the *touch* definition was used, perhaps due to the lower performance with this definition leaving more room for improvement.

Analyses of performance according to different response definitions corroborated findings by Kabadayi, Krasheninnikova et al. (2017), in which performance was better when only touches directed towards the location of the reward were counted as errors, rather than any contact with any part of the cylinder. More notable, however, was the finding that cylinder task performance only related to DIAS scores (Behavioral Regulation subscale) when the typical *touch* definition was used and when the treat was the reward. Importantly, the Behavioral Regulation subscale consists of questions regarding dogs' ability to inhibit prepotent responses and is the subscale most likely to reflect dogs' inhibitory control abilities (Piotti, Satchell et al., 2018; Wright et al., 2011). To our knowledge, this is the first evidence of a relationship between cylinder task performance and an external measure of inhibitory control in dogs. Finding this relationship only when using the *touch* definition conflicts with our hypothesis, based on Kabadayi, Krasheninnikova et al., (2017), that errors directed towards the location of the reward would more likely reflect true inhibitory control failure. It may be that, for this population especially, bumping into the cylinder does not represent an aversive experience that the dog would be motivated to avoid by exerting inhibitory control. In fact, dogs were often observed pouncing on the cylinder which may have been rewarding in itself. However, finding this relationship only when using the treat may be because the lower arousal produced by the treat compared to the ball is a better reflection of inhibitory control skills. We suggest that in this population of high-arousal, ball-driven dogs, decreasing task difficulty (i.e., by using a less arousal-inducing reward) created enough variability in performance to reveal this relationship. Conversely, we suggest that increasing task difficulty by manipulating task features, such as increasing arousal (Bray et al., 2015), decreasing the size (Bobrowicz & Osvath, 2018) or distance (Regolin et al., 1994) of the apparatus, or increasing the cost of an incorrect response may help uncover these relationships in other populations of dogs or other species (e.g., those that often demonstrate ceiling effects on detour tasks).

Other factors not controlled for in our study may have led to differences between the conditions and/or definitions. For example, visual disparities in the size or color of the rewards may have influenced their visibility or salience. Further, the relatively large size of the ball in proportion to the middle section used for scoring *towards* responses may have influenced performance (e.g., limiting touches to the center section may have inaccurately omitted touches from other angles).

To our knowledge, this study is the first to examine the effect of reward type on dogs' performance in the cylinder task. We found that the type of reward used significantly affected dogs' ability to correctly detour, suggesting that characteristics of the reward can decrease inhibitory control. We also found that general reward preference influenced performance, which may reflect underlying individual differences. We suggest that the mechanisms for these effects may be through arousal, though further research is needed to confirm. Further, we found that cylinder task performance related to an external measure of inhibitory control. These findings have implications for studies of inhibitory control, indicating that methodological features can influence the results and the validity of the task. Our results also have implications for dog training, suggesting that the type of reward used should be strategically selected to manage arousal that can impact performance (Stokke, 2015). However, our findings are based on a specific breed and sample with a training history that likely influences their inhibitory control (Barrera et al., 2019). Therefore, future research is needed to determine the generalizability of our results.

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Data availability statement: All data and code for analyses are available at: https://github.com/szk0138/Reward-type-affects-dogs-performance-in-the-cylinder-task

Author Contributions: LL: Conceptualization, SK: Formal Analysis, SK and LL: Methodology, Writing - Original Draft, Writing – Review & Editing

Conflict of Interest: The authors declare that they have no conflict of interest

References

Barrera, G., Alterisio, A., Scandurra, A., Bentosela, M., & D'Aniello, B. (2019). Training improves inhibitory control in water rescue dogs. *Animal Cognition*, *22*(1), 127–131. https://doi.org/10.1007/s10071-018-1224-9

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Bobrowicz, K., & Osvath, M. (2018). Cats parallel great apes and corvids in motor self-regulation—Not brain but material size matters. *Frontiers in Psychology*, *9*, 1–8. https://doi.org/10.3389/fpsyg.2018.01995

Bray, E. E., MacLean, E. L., & Hare, B. A. (2014). Context specificity of inhibitory control in dogs. *Animal Cognition*, *17*(1), 15–31. https://doi.org/10.1007/s10071-013-0633-z

Bray, E. E., MacLean, E. L., & Hare, B. A. (2015). Increasing arousal enhances inhibitory control in calm but not excitable dogs. *Animal Cognition*, *18*(6), 1317–1329. https://doi.org/10.1007/s10071-015-0901-1

Bray, E. E., Gruen, M. E., Gnanadesikan, G. E., Horschler, D. J., Levy, K. M., Kennedy, B. S., Hare, B. A., & MacLean, E. L. (2021). Dog cognitive development: A longitudinal study across the first 2 years of life. *Animal Cognition*, *24*(2), 311–328. https://doi.org/10.1007/s10071-020-01443-7

Bray, E. E., Otto, C. M., Udell, M. A. R., Hall, N. J., Johnston, A. M., & Maclean, E. L. (2021). Enhancing the selection and performance of working dogs. *Frontiers in Veterinary Science, 8*, 430. https://doi.org/10.3389/fvets.2021.644431

Brucks, D., Marshall-Pescini, S., Wallis, L. J., Huber, L., & Range, F. (2017). Measures of dogs' inhibitory control abilities do not correlate across tasks. *Frontiers in Psychology*, *8*, 849. https://doi.org/10.3389/FPSYG.2017.00849

Brucks, D., Soliani, M., Range, F., & Marshall-Pescini, S. (2017). Reward type and behavioural patterns predict dogs' success in a delay of gratification paradigm. *Scientific Reports*, *7, 42459*. https://doi.org/10.1038/srep42459

Fadel, F. R., Driscoll, P., Pilot, M., Wright, H., Zulch, H., & Mills, D. (2016). Differences in trait impulsivity indicate diversification of dog breeds into working and show lines. *Scientific Reports*, *6*, 1–10. https://doi.org/10.1038/srep22162

Fagnani, J., Barrera, G., Carballo, F., & Bentosela, M. (2016). Is previous experience important for inhibitory control? A comparison between shelter and pet dogs in A-not-B and cylinder tasks. *Animal Cognition*, *19*(6), 1165–1172. https://doi.org/10.1007/s10071-016-1024-z

Foraita, M., Howell, T., & Bennett, P. (2021). Environmental influences on development of executive functions in dogs. *Animal Cognition*, *24*(4), 655–675. https://doi.org/10.1007/s10071-021-01489-1

Gerencsér, L., Bunford, N., Moesta, A., & Miklósi, Á. (2018). Development and validation of the canine reward responsiveness scale–examining individual differences in reward responsiveness of the domestic dog. *Scientific Reports*, *8*(1), 1–14. https://doi.org/10.1038/s41598-018-22605-1

Junttila, S., Huohvanainen, S., & Tiira, K. (2021). Effect of sex and reproductive status on inhibitory control and social cognition in the domestic dog (*Canis familiaris*). *Animals*, *11*(8), 2448. https://doi.org/10.3390/ani11082448

Kabadayi, C., Bobrowicz, K., & Osvath, M. (2018). The detour paradigm in animal cognition. *Animal Cognition*, *21*(1), 21–35. https://doi.org/10.1007/s10071-017-1152-0

Kabadayi, C., Jacobs, I., & Osvath, M. (2017). The development of motor self-regulation in ravens. *Frontiers in Psychology*, *8*, 2100. https://doi.org/10.3389/fpsyg.2017.02100

Kabadayi, C., Krasheninnikova, A., O'Neill, L., van de Weijer, J., Osvath, M., & von Bayern, A. M. P. (2017). Are parrots poor at motor self-regulation or is the cylinder task poor at measuring it? *Animal Cognition*, *20*(6), 1137–1146. https://doi.org/10.1007/s10071-017-1131-5

Kelly, D. M., Adolphe, J. L., Vernouillet, A., McCausland, J. A., Rankovic, A., & Verbrugghe, A. (2019). Motoric self-regulation by sled dogs and pet dogs and the acute effect of carbohydrate source in sled dogs. *Animal Cognition*, *22*(6), 931–946. https://doi.org/10.1007/s10071-019-01285-y

Lazarowski, L., Krichbaum, S., Waggoner, L. P., & Katz, J. S. (2020). The development of problem-solving abilities in a population of candidate detection dogs (Canis familiaris). *Animal Cognition*, *23*(4), 755–768. https://doi.org/10.1007/s10071-020-01387-y

Lazarowski, L., Rogers, B., Krichbaum, S., Haney, P., Smith, J. G., & Waggoner, P. (2021). Validation of a behavior test for predicting puppies' suitability as detection dogs. *Animals*, *11*(4), 993. https://doi.org/10.3390/ani11040993

Lazarowski, L., Waggoner, L. P., Krichbaum, S., Singletary, M., Haney, P., Rogers, B., & Angle, C. (2020). Selecting dogs for explosives detection: Behavioral characteristics. *Frontiers in Veterinary Science*, *7*, 597. https://doi.org/10.3389/fvets.2020.00597

MacLean, E., & Hare, B. (2018). Enhanced selection of assistance and explosive detection dogs using cognitive measures. *Frontiers in Veterinary Science*, *5*, 236. https://doi.org/10.3389/FVETS.2018.00236

MacLean, E. L., Hare, B., Nunn, C. L., Addessi, E., Amici, F., Anderson, R. C., ... Zhao, Y. (2014). The evolution of self-control. *Proceedings of the National Academy of Sciences*, *111*(20), E2140-E2148. https://doi.org/10.1073/pnas.1323533111

Marshall-Pescini, S., Virányi, Z., & Range, F. (2015). The effect of domestication on inhibitory control: Wolves and dogs compared. *PLoS ONE*, *10*(2), 1–16. https://doi.org/10.1371/journal.pone.0118469

Mehrkam, L. R., Hall, N. J., Haitz, C., & Wynne, C. D. (2017). The influence of breed and environmental factors on social and solitary play in dogs (*Canis lupus familiaris*). *Learning & Behavior*, *45*(4), 367–377. https://doi.org/10.3758/s13420-017-0283-0

Mongillo, P., Araujo, J. A., Pitteri, E., Carnier, P., Adamelli, S., Regolin, L., & Marinelli, L. (2013). Spatial reversal learning is impaired by age in pet dogs. *AGE*, *35*(6), 2273–2282. https://doi.org/10.1007/s11357-013-9524-0

Nieuwenhuis, R., Grotenhuis, M., & Pelzer, B. (2012). influence.ME: Tools for detecting influential data in mixed effects models. *R Journal*, *4*(2), 8-47

Piotti, P., Satchell, L. P., & Lockhart, T. S. (2018). Impulsivity and behaviour problems in dogs: A reinforcement sensitivity theory perspective. *Behavioural Processes*, *151*, 104–110. https://doi.org/10.1016/j.beproc.2018.03.012

Piotti, P., Szabó, D., Bognár, Z., Egerer, A., Hulsbosch, P., Carson, R. S., & Kubinyi, E. (2018). Effect of age on discrimination learning, reversal learning, and cognitive bias in family dogs. *Learning & Behavior*, *46*(4), 537–553. https://doi.org/10.3758/s13420-018-0357-7

Raffan, E., Dennis, R. J., O'Donovan, C. J., Becker, J. M., Scott, R. A., Smith, S. P., ...O'Rahilly, S. (2016). A deletion in the canine POMC gene is associated with weight and appetite in obesity-prone labrador retriever dogs. *Cell Metabolism*, *23*(5), 893–900. https://doi.org/10.1016%2Fj.cmet.2016.04.012

Regolin, L., Vallortigara, G., & Zanforlin, M. (1994). Perceptual and motivational aspects of detour behaviour in young chicks. *Animal Behaviour*, 47, 123–131. https://doi.org/10.1006/anbe.1994.1014

Shaw, R. C. (2017). Testing cognition in the wild: Factors affecting performance and individual consistency in two measures of avian cognition. *Behavioural Processes*, *134*, 31–36. https://doi.org/10.1016/j.beproc.2016.06.004

Stokke, T. (2015). *The effect of reward type and reward preference on the performance of detection dogs* [unpublished Master's thesis]. Norwegian University of Life Sciences.

Tapp, P. D., Siwak, C. T., Estrada, J., Head, E., Muggenburg, B. A., Cotman, C. W., & Milgram, N. W. (2003). Size and reversal learning in the beagle dog as a measure of executive function and inhibitory control in aging. *Learning & Memory*, *10*(1), 64–73. https://doi.org/10.1101/lm.54403

Tiira, K., Tikkanen, A., & Vainio, O. (2020). Inhibitory control – Important trait for explosive detection performance in police dogs? *Applied Animal Behaviour Science*, *224*, 104942. https://doi.org/10.1016/j.applanim.2020.104942

Van Bourg, J., Gilchrist, R., & Wynne, C. D. (2021). Adaptive spatial working memory assessments for aging pet dogs. *Animal Cognition*, *24*(3), 511–531. https://doi.org/10.1007/s10071-020-01447-3

van Horik, J. O., Langley, E. J. G., Whiteside, M. A., Laker, P. R., Beardsworth, C. E., & Madden, J. R. (2018). Do detour tasks provide accurate assays of inhibitory control? *Proceedings. Biological Sciences*, *285*(1875), 20180150. https://doi.org/10.1098/rspb.2018.0150

Vernouillet, A. A. A., Stiles, L. R., Andrew McCausland, J., & Kelly, D. M. (2018). Individual performance across motoric self-regulation tasks are not correlated for pet dogs. *Learning and Behavior*, 522–536. https://doi.org/10.3758/s13420-018-0354-x

Vernouillet, A., Anderson, J., Clary, D., & Kelly, D. M. (2016). Inhibition in Clark's nutcrackers (*Nucifraga columbiana*): Results of a detour-reaching test. *Animal Cognition*, *19*(3), 661–665. https://doi.org/10.1007/s10071-016-0952-y

Vlamings, P. H. J. M., Hare, B., & Call, J. (2010). Reaching around barriers: The performance of the great apes and 3-5-year-old children. *Animal Cognition*, *13*(2), 273–285. https://doi.org/10.1007/s10071-009-0265-5

Wright, H. F., Mills, D. S., & Pollux, P. M. (2011). Development and validation of a psychometric tool for assessing impulsivity in the domestic dog (*Canis familiaris*). *International Journal of Comparative Psychology*, *24*(2), 210-225.