

# Cognitive assessment for neuropsychological impairments in dogs (CANID): an efficient, repeatable, and sensitive evaluation for studies of cognitive aging

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## Abstract

We introduce the Cognitive Assessment for Neuropsychological Impairments in Dogs (CANID), a functional evaluation consisting of three cognitive tasks that measure aspects of memory and executive function. CANID can be implemented in a single ~40-min evaluation, was designed for studies of cognitive aging in community dwelling dogs, and is sensitive to age-related cognitive differences beginning in mid-life. We developed a scoring system using a baseline sample ( $N = 239$ ) and repeat testing at six ( $N = 138$ ) and twelve ( $N = 114$ ) month follow-up. Overall CANID scores had substantial repeatability at six ( $ICC = 0.63$ , 95% CI [0.51, 0.72]) and twelve ( $ICC = 0.59$ , 95% CI [0.47, 0.70]) months, as did all task-specific subscores. CANID scores at 6-month follow-up suggested modest practice effects (0.23 SD improvement in overall score relative to baseline), similar to those reported in human studies, but we did not find evidence for practice effects at one-year follow-up. To facilitate CANID's use, we provide detailed protocols, video libraries, data recording instruments, experimenter training guidelines, and R code for scoring in an Open Science Framework repository.

## Introduction

Dogs are a valuable natural model for human cognitive decline and dementia given that many dogs spontaneously develop age-related cognitive impairment, which is sometimes accompanied by neuropathological changes resembling features of Alzheimer's disease.

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In studies with laboratory populations, cognitive impairments have been measured using standardized behavioral assays, which can detect mild cognitive impairment that often begins in midlife, at as early as six years of age (Cummings et al. 1996; Snigdha et al. 2012; Studzinski et al. 2006; Tapp et al. 2004). However, these tests are time- and labor- intensive and rely on operant training protocols that are not feasible for large populations of community-dwelling companion dogs. Among companion dogs, cognitive aging and dementia has predominantly been studied using owner-report questionnaires (Madari et al. 2015; Salvin et al. 2011). Though valuable and highly scalable, questionnaires are inherently subjective and do not provide direct, functional assessments of cognition. Rather, these questionnaires measure behavioral signs of dementia, which may only emerge in later stages of decline when behavioral changes become noticeable because they significantly impact the daily lives of dogs and their families (Chapagain et al. 2017a, b; Olby et al. 2026). Thus, there is an important need for objective functional assessments of cognition that can detect early stages of cognitive dysfunction and which can be easily administered within large samples of companion dogs. Toward this aim, several standalone tasks and sets of measures have been developed and used in recent studies of companion dog aging (Chapagain et al. 2020; González-Martínez et al. 2013; Hoel et al. 2021; Kubinyi & Iotchev 2020; Mongillo et al. 2013; Piotti et al. 2018, 2022; Sanches et al. 2022; Simon et al. 2025; Van Bourg et al. 2021).

Assessment of test–retest reliability is a frequent part of the development of cognitive and psychological measures in humans (Calamia et al. 2013) and has been used in questionnaire measures developed to assess dog behavior, personality, or temperament via owner-report (Duffy & Serpell 2008; Ley et al. 2009; Salonen et al. 2021; Tiira & Lohi 2014) and in behavioral tasks designed to quantify dog temperament (Harvey et al. 2016; Turcsán et al. 2018). However, it has historically been rare for animal cognition researchers to do the same when designing cognitive tasks for nonhuman species (Kubinyi & Iotchev 2020; Schubiger et al. 2020; Shaw & Schmelz 2017). Few canine cognition studies have quantified the stability of cognitive traits over time, and methods by which repeatability is quantified vary. Some have quantified developmental stability from early life to adulthood (Bray et al. 2021) while others focus on consistency within adults (Bognár et al. 2024; Junttila et al. 2024; Piotti et al. 2022). Repeatability is often under-addressed in studies of animal cognition generally, despite being a crucial element for establishing validity and reproducibility. Cauchoix et al. (2018) conducted a meta-analysis of contextual and temporal repeatability of cognitive measures across many animal taxa, including humans. They demonstrated consistent individual differences in cognition, with a significant yet low average estimate for temporal repeatability. Data from human and nonhuman animal studies compiled by Cauchoix et al. (2018) suggest that cognitive measures may be less repeatable than measures of temperament and personality. Additionally, their meta-analysis suggested negligible learning effects with repeated task exposure and no effect of the delay interval between repeated testing on repeatability.

In one of the few assessments of test–retest reliability in dog cognition, Bognár et al. (2024) reported good repeatability for composite scores and factors related to individual problem solving and learning, but poor repeatability for measures of point-following and sustained visual attention. Junttila et al. (2024) also observed that repeatability varies across different task types, ranging from slight to moderate. Jointly, these results suggest that differences in repeatability may stem from the type of task used or cognitive domain assessed. Bognár et al. (2024) also note decreasing repeatability with increasing length of time between tests, especially intervals greater than 2.5 years, which could be attributable to cognitive aging in their study population. Other papers have assessed overall change across time by comparing mean differences at various timepoints and find no substantive change in overall scores (Piotti et al. 2022; Simon et al. 2025).

In addition to assessing test–retest reliability, it is important to quantify any improvement in scores due to learning, especially in tests used for longitudinal research (Di Bari et al. 2002). Practice effects (systematic improvement with repeated exposure to a test) can interfere with longitudinal studies of cognition. For example, in human studies, practice effects can obscure detection of mild cognitive impairment (Sanderson-Cimino et al. 2022). Knowing the extent to which participants improve with repeated task exposure can allow researchers to account for that systematic improvement in analyses. Conversely, variation in learning across time may reflect

aspects of cognitive decline. In tasks where practice effects are normal and expected, the *absence* of improvement with repeated testing (or a lesser degree of improvement) may signal current or future cognitive impairment (Jutten et al. 2020). In animal cognition, learning effects are uncommonly assessed, but it seems that some task types, such as those designed to measure inhibitory control, may be especially susceptible to improvement with repeat exposures (Loyant et al. 2025; Salomons et al. 2026).

Previously, we developed the preliminary version of a test battery intended to capture age-related cognitive decline in companion dogs; for the present study, we aimed to refine this battery and evaluate its test–retest reliability. In our prior study, we reported results from a novel battery of five spontaneous problem-solving tasks measuring aspects of spatial learning and memory, response flexibility, and social behavior (Hargrave et al. 2025). In a diverse sample of companion dogs, age-related impairment was detectable in middle age (~8 years of age), and on average, older dogs performed substantially worse on measures of spatial memory, spatial reversal learning, and inhibitory control. We also demonstrated feasibility for these tasks in clinical settings. However, the 5-task battery was relatively lengthy, requiring administration across two 30–60-min sessions. Additionally, our analyses were cross-sectional, precluding assessment of repeatability or practice effects, both important considerations for longitudinal designs.

Here we report the development of, and initial studies using, the Cognitive Assessment for Neuropsychological Impairments in Dogs (CANID). CANID is a streamlined battery based on the measures developed in Hargrave et al. (2025), with modifications to enable completion in a single study visit. We model relationships between CANID scores and age, assess repeatability at 6- and 12-month intervals, and probe whether repeated testing is associated with practice effects.

Our objective in developing CANID was to facilitate more rapid and streamlined data collection, enabling acquisition of all measures within a single 40–60 min session while maintaining sensitivity to age-associated differences in cognition. We therefore began with the three tasks most strongly associated with age in Hargrave et al. (2025), measuring response flexibility, short-term spatial memory, and inhibitory control. Additionally, we refined two of the three tasks to reduce administration time. We also aimed to assess the feasibility of using CANID in longitudinal studies.

We present data from an ongoing longitudinal study in which 239 dogs underwent baseline CANID testing, with follow-up assessments at six and twelve months (6-month  $N = 138$ , 12-month  $N = 114$ ). Using these data, we estimate 1) relationships between cognitive performance and dog age, 2) repeatability across different time scales, and 3) practice effects associated with repeated testing.

## Methods

Methodological details regarding study procedures are reprinted with modifications from, GeroScience, 47, Hargrave et al. (2025), “Characterizing dog cognitive aging using spontaneous problem-solving measures: development of a battery of tests from the Dog Aging Project”, with permission from Springer. We provide a comprehensive methods manual and other materials for implementation of these methods in an OSF repository (see “[Availability of CANID Methods Manual and Resources](#)”).

## Participants and data collection sites

Data collection occurred at three sites including a university research laboratory (Arizona Canine Cognition Center, Tucson, AZ, USA), a dog daycare facility (Sit! Stay! Play!, Tucson, AZ, USA), and a service dog training center (Canine Companions, Santa Rosa, CA, USA). Demographic information for participating dogs is provided in Table 1. Dogs tested at the Arizona Canine Cognition Center were recruited from a database of local dog owners who had expressed interest in participation in cognitive and behavioral studies. In this database, owners provide information about their dog’s behavioral and medical history. Dogs noted as having a history of human-directed

**Table 1** Selected demographic information for dogs participating in the development and testing of CANID. N represents the total number of dogs contributing data for at least one of three cognitive tasks at each assessment. At baseline, an additional nine dogs were enrolled but contributed no data because of fear or lack of food motivation and are not included in this table. See ESM Table 4 for further detail on the sample size for each task at each timepoint

|                                 | Baseline |                                |  | 6-month retest |                                |  | 12-month retest |                                |  |
|---------------------------------|----------|--------------------------------|--|----------------|--------------------------------|--|-----------------|--------------------------------|--|
|                                 | N        | Mean (SD) [Range] <sup>1</sup> |  | N              | Mean (SD) [Range] <sup>1</sup> |  | N               | Mean (SD) [Range] <sup>1</sup> |  |
| Age (years)                     | 239      | 7.0 (4.0) [0.8–16.1]           |  | 138            | 7.5 (3.9) [1.3–16.6]           |  | 114             | 7.3 (3.9) [1.8–15.3]           |  |
| Weight (kg)                     | 239      | 22.5 (10.8) [3.6–54.4]         |  | 138            | 22.5 (10.8) [3.6–54.4]         |  | 114             | 23.5 (10.8) [3.6–54.4]         |  |
| Sex                             | 239      |                                |  | 138            |                                |  | 114             |                                |  |
| Spayed female                   | 109      | 46%                            |  | 60             | 43%                            |  | 51              | 45%                            |  |
| Neutered male                   | 109      | 46%                            |  | 68             | 49%                            |  | 56              | 49%                            |  |
| Intact female                   | 12       | 5%                             |  | 3              | 2%                             |  | 1               | 1%                             |  |
| Intact male                     | 9        | 4%                             |  | 7              | 5%                             |  | 6               | 5%                             |  |
| Test Location                   | 239      |                                |  | 138            |                                |  | 114             |                                |  |
| Arizona Canine Cognition Center | 116      | 49%                            |  | 65             | 47%                            |  | 43              | 38%                            |  |
| Canine Companions               | 31       | 13%                            |  | 1              | 1%                             |  | 21              | 18%                            |  |
| Sit! Stay! Play!                | 92       | 38%                            |  | 72             | 52%                            |  | 50              | 44%                            |  |
| Breed Category                  | 239      |                                |  | 138            |                                |  | 114             |                                |  |
| Mixed breed                     | 121      | 51%                            |  | 58             | 42%                            |  | 51              | 45%                            |  |
| Purebred                        | 118      | 49%                            |  | 80             | 58%                            |  | 63              | 55%                            |  |

<sup>1</sup>For categorical variables, values reflect the percent of the sample in each category

aggression, fear of people, intense fear of veterinary visits, or who were reported to have severe vision or mobility impairments, were not invited. Dogs tested at the dog daycare facility were recruited through informational flyers provided to clients. Dogs tested at the service dog training center were recruited through word of mouth and electronic invitations to dog owners near the data collection site. Because we aimed to characterize cognitive performance across the lifespan, we recruited dogs of approximately 1 to 16 years of age (Table 1).

## General methods

Dogs participated in a battery of three tasks administered in a single session lasting approximately 40–60 min. The three tasks were designed to measure aspects of memory and executive function and included a response flexibility task (Spatial Reversal), a short-term spatial memory task (Delayed Search), and an inhibitory control task (Cylinder). The battery also included a brief assessment of vision and hearing (Sensory Screen). These tasks were identical to or adapted with minor modifications (described below) to reduce time requirements, from Hargrave et al (2025).

A subset of dogs (ESM Table 1) participated in a preliminary version of this battery described in Hargrave et al. (2025) which included the same three tasks plus two additional tasks. For the two tasks that were truncated from the preliminary to the current version, data for these dogs were restricted to the same number of trials to allow direct comparison to data from the current, shorter versions. Detailed methods for each task, presented in order of administration, are described in the subsections below.

All tasks involved a handler who positioned the dog at a start location and timed the trials, and an experimenter who administered the test and recorded data. All sessions were video recorded and behavioral responses were coded in real time. A random subset of  $\geq 20\%$  of trials from all tasks were later coded from video by a second observer to assess inter-rater reliability (see “Statistical Analysis”).

All tasks were designed as problem-solving activities in which dogs participated for food rewards. Dogs were not systematically fasted prior to participation. However, owners were informed that it may be helpful to avoid feeding them within a few hours prior to testing and/or to give them a partial rather than a full meal ahead of testing, particularly if their dog was likely to be satiated by 40 small treats. Food rewards were typically small pieces of commercial meat-based dog treats (Jerky Treats, distributed by Big Heart Pet Brand, Orrville, OH) or

kibble from the dog's typical diet, but occasionally varied according to dog preferences or dietary restrictions. In our initial work, an odor control task confirmed that dogs were unable to choose accurately in these tasks based on olfactory cues (Hargrave et al. 2025).

A total of 20 experimenters administered CANID. Some experimenters were trained prior to the beginning of the study, while others were trained on an ongoing basis as needed to support data collection. New experimenters underwent a detailed training process which required study of written protocols, review of videos from prior experiments, observation of trained experimenters, practice sessions implementing protocols, and supervision by a trained experimenter during initial formal data collection. A full methods manual and materials to support training of research staff in CANID implementation is provided on OSF (see “[Availability of CANID Methods Manual and Resources](#)”).

Across all tasks, if a dog did not move from the starting position when the experimenter said “okay” (the cue to release the dog), the experimenter repeated the “okay” release cue at 2-s intervals, up to a total of three times. If the dog had not initiated a response (e.g., moved forward to search) by the third release cue, the handler gently nudged the dog from behind to encourage them to move forward from the start line without directing them towards any particular choice location (Delayed Search) or side (Cylinder and Spatial Reversal). If at any point a dog became fearful or anxious during testing and was not easily soothed, we discontinued data collection for that task (Spatial Reversal  $N = 6$ , Delayed Search  $N = 2$ ; no dogs aborted the Cylinder task due to fear). If a dog exhibited fear, anxiety, or stress at the beginning of a session and did not become comfortable within approximately 10–15 min of acclimation, no data collection occurred ( $N = 6$ ). Likewise, no data collection occurred if a dog was hesitant to consume the food rewards offered freely during acclimation ( $N = 3$ ).

At the Arizona Canine Cognition Center, owners were present (positioned in a neutral location behind the dog during testing) in addition to the experimenter and handler, but owners were typically absent during testing at the other locations.

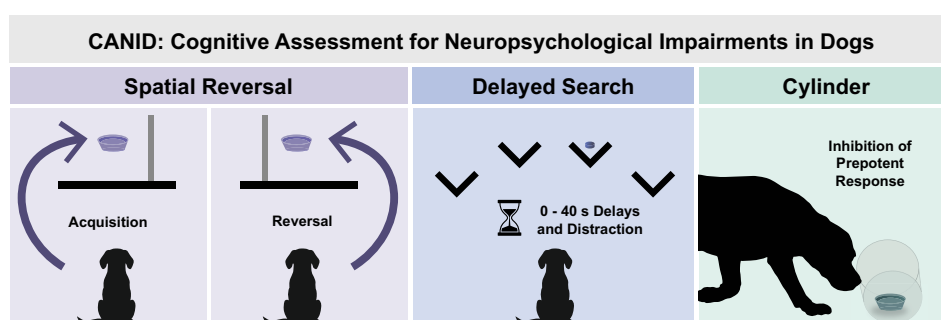
The procedures described below are presented in order of administration. Each task consisted of a flexible, unscored warm-ups phase that ensured dogs were comfortable approaching the apparatus and, in the case of the Delayed Search and Cylinder tasks, allowed dogs to learn how to access food from behind v-shaped blinds and within the Cylinder, respectively. The warm-ups phase was followed by a series of scored test trials. Schematics illustrating the three cognitive tasks are shown in Fig. 1.

## Spatial reversal

This task measured a dog's response flexibility, or ability to adapt their behavior to changing circumstances, in the context of a spatial memory task.

**Warm-up trial.** The warm-up trial served to ensure dogs were comfortable approaching and eating near the apparatus. Dogs were positioned at a start line 1.83 m in front of a freestanding 0.91 m × 0.91 m panel. In the warm-up trial, the experimenter showed the dog a treat, placed it into a metal bowl (height = 75 cm, diameter = 180 cm), and then placed the bowl on the ground in front of the panel such that it was visible to the dog. The

**Fig. 1** Schematic of the three cognitive tasks in CANID



dog was then released and allowed 20 s to obtain the food reward from the bowl. If dogs were not immediately comfortable approaching on the first attempt of the warm-up trial, they were encouraged to retrieve the treat, and the warm-up trial was repeated until they readily approached and consumed the food without encouragement.

*Side choice trial.* The side choice trial was used to determine the dog's initial preferred direction of approach. In the side choice trial, the experimenter stood centered behind the panel and held a treat above the panel such that it was visible to the dog. The experimenter then visibly placed the treat into the bowl and lowered the bowl behind the panel, placing it on the ground. The experimenter turned around to face away from the dog as the handler released the dog to search for the food behind the panel, which could be obtained by detouring to either the left or right side of the panel. If a dog did not obtain the reward within 20 s, the trial was repeated, and if the dog failed to obtain the reward within three trials, data collection was discontinued. The side choice trial did not contribute to scoring, but the side from which the dog approached on this trial determined the setup for the baseline phase of the task.

In all subsequent baseline and reversal test trials, the procedure was identical to that of the side choice trial with the exception that a barrier (0.61 m wide  $\times$  0.91 m tall) was positioned behind the front panel, which prevented the dog from accessing the food from one side. The barrier blocking access to the food from one side was not visible to the dog from the dog's start line.

*Baseline test trials.* For the baseline block, the closed side was the side not initially chosen (i.e., if a dog navigated to the left side of the panel in the side choice trial, the barrier prevented approaches to the right in subsequent trials). The barrier was constructed of wire mesh such that if the dog approached the closed side, they could see (but not access) the food reward, as well as the open path on the opposite side of the apparatus. During baseline test trials, dogs were allowed up to 20 s from the start of the trial to use the open path to access the reward. The trial ended when the dog accessed the reward within the allotted 20 s. During both the baseline phase and the subsequent reversal phase, if a dog approached the closed side but was unable to detour to the open side on their own, the dog was led to the open side by the handler and allowed to obtain the reward. The handler showing the dog how to access food served to maintain motivation to search and equalize dogs' experience of accessing food at the open side, ensuring that on every trial, if they chose a side, dogs gained experience obtaining the reward via the open path. If the dog did not approach either side of the apparatus (scored as "no choice," which was neither correct nor incorrect), the dog was not led to the open side, but instead was given a "motivator trial" allowing them easy access to the food placed in a bowl in front of the apparatus (identical to the warm-up trial), followed by a repeat of the test trial on which the no choice occurred. On each trial, we recorded the side first approached, operationally defined as the side on which the dog first placed any paw into a marked proximity zone (43 cm  $\times$  20 cm). Before moving on to the next phase, dogs were required to meet a criterion of first approaching the open path in three of four consecutive trials (not including their initial side choice that determined the open side in baseline trials). If a dog did not meet baseline criterion within 20 trials, the Spatial Reversal task was stopped, and the dog continued to subsequent tasks.

*Reversal test trials.* In each reversal block, the barrier was shifted to the opposite end of the panel, closing the path that had been open on the preceding trials, and opening the path on the opposite side. Thus, dogs were required to inhibit the previously successful response and instead employ a new response to access the reward. Trials were repeated in the reversed configuration until the dog chose to first approach the open path in three of four consecutive trials. Upon meeting this criterion, the position of the barrier was reversed again, and another block of trials was administered. This general procedure continued until the dog met the criterion on a total of three reversal blocks, or a total of 20 trials had elapsed during this stage of the task (reversal trials), whichever occurred first. Throughout all phases of the Spatial Reversal task, no delay was imposed between trials; rather, the subsequent trial began as soon as the dog was repositioned at the start line.

*Dependent measures:*

1. The total number of blocks the dog completed (the number of blocks in which criterion was met, including the baseline block and up to 3 reversal blocks – range 0–4, lower numbers indicative of worse cognitive functioning)
2. The number of trials in the dog's single longest block (range 4–20, higher numbers indicative of worse cognitive functioning)
3. The number of unused trials remaining out of 20 possible trials at the conclusion of the task (e.g., 0 for any dog that did not complete three reversals within 20 trials in the reversal phase, lower numbers indicative of worse cognitive functioning)

Dogs who did not meet baseline criterion within the 20 allotted trials and thus did not proceed to the reversal phase (see “Baseline test trials”) were assigned the worst possible score, with a longest block length of 20 trials, 0 trials remaining, and a total of 0 (of 4 possible) phases completed.

We used Principal Component Analysis to generate a Spatial Reversal summary score using these three dependent measures as the input (see [Statistical Analysis](#)).

## Delayed search

This task assessed a dog's ability to remember the location of a hidden reward across increasing retention intervals, and in the context of distractions.

*Warm-up trials.* The Delayed Search task requires dogs to search for food rewards hidden behind v-shaped blinds placed on the ground. Before beginning test trials, we conducted a warm-up procedure to acclimate dogs to the blinds and the process of searching for food behind them. Across the warm-up trials and the subsequent test trials, treats were positioned at the apex of the baited blind(s) such that they were not visible to the dog unless the dog looked down into the blind from above. During the warm-up, a single blind was positioned in a central location and the experimenter placed a treat behind the blind as the dog watched. The dog was then immediately released to search for the food and was led to the treat by the experimenter if they did not quickly find it on their own. This process was repeated until the dog reliably searched for and located a treat placed behind a single blind. The experimenter then presented the dog with two blinds, positioned equidistantly in front of the dog in a central area of the room, and placed a single treat behind one of the blinds as the dog watched. Again, the dog was immediately released to search for the hidden food, and the experimenter helped the dog to locate the reward if they did not quickly find it independently. This process was repeated until the dog independently approached the baited blind first on at least two occasions. After dogs learned to search for rewards behind blinds, we briefly familiarized them with the procedure that would be used as a distraction in test trials (see below). The experimenter walked rapidly towards the dog and placed a treat on the ground directly in front of the dog, then immediately turned around and returned to their starting position.

*Test trials.* Four blinds were arranged in an array 2.74 m from the dog's starting point, such that all blinds were equidistant from the dog. On each trial, the experimenter showed the dog a treat, and as the dog watched, placed it behind one of the blinds. Dogs were released immediately once the experimenter returned to their starting position after baiting in the first four test trials (no delay). In the remaining eight test trials, dogs were required to wait for a specified duration before being released to search. We used three fixed delays of 10 s (4 trials), 20 s (2 trials), and 40 s (2 trials), which were administered sequentially. The first two test trials were identical to the no-delay trials except that dogs were required to wait 10 s before searching. In the remaining six test trials, we implemented a distraction to prevent dogs from using non-mnemonic strategies such as sustained attention or body orientation towards the hidden reward (Krichbaum et al. 2021). In these distraction trials, during the delay (after placing a treat behind a blind), the experimenter walked towards the dog and delivered a small food reward on the ground in front of the dog, then returned to their starting position. To consume this reward, dogs were required to lower their heads, breaking any possible fixation on the blinds. Additionally, the dogs' view of the blinds became momentarily obscured by the experimenter's body. For each test trial, dogs were given 20 s

to search for the hidden reward. We recorded the first location that the dog searched, operationally defined as the dog's snout entering the corner of the blind or the dog's head being positioned above the area behind the blind with a downward head orientation. If the first location the dog searched was incorrect, we allowed the dog to continue searching until 20 s had elapsed, or until the reward was located. If the dog searched in at least one location but did not locate the treat within 20 s, to prevent declines in motivation associated with failure to obtain a reward, the handler led them to the baited location and allowed them to eat the treat. However, if the dog did not search in any blinds (scored as "no choice"), the dog was not shown the food but was instead returned to the start line and participated in a "motivator trial" in which the experimenter placed a single blind directly in front of the dog, baited it, and released the dog immediately. If the "no choice" occurred on a distraction trial, the motivator trial incorporated the delivery of a distraction treat as well but still had only one blind available for the dog to choose from. Following the motivator trial, the trial in which the "no choice" occurred was repeated. If the dog made four "no choices" during the test trials, the task was discontinued ( $N = 3$  dogs across timepoints, of which all three provided sufficient data for imputation of remaining trials).

The reward location was balanced across trials (three times in each location) and was never the same on consecutive trials. The reward location followed the same predetermined order for all dogs.

*Dependent measures.* For this task, we assessed the proportion of correct trials within each trial type (i.e., no delay, 10-s delay, 10-s delay with distraction, 20-s delay with distraction, 40-s delay with distraction). For a small subset of dogs who did not make choices on all trials ( $N = 15$ ), we imputed missing data using predictive mean matching, implemented in the **multiple imputation through chained equations** (mice) R package (Buuren & Groothuis-Oudshoorn 2011).

We used Principal Component Analysis to generate a Delayed Search summary score using proportion correct on each trial type as the input (see [Statistical Analysis](#)).

## Cylinder

This task measured a dog's motor inhibition and response flexibility in the context of changing task demands.

*Warm-up trials.* Warm-up trials used an opaque black cylinder (26.5 cm in length) with an opening at one end (diameter 22.5 cm) that was positioned 1.24 m from the dog. The experimenter acclimated the dog to approaching the cylinder by performing one trial in which they placed a small silicone bowl (height = 2.5 cm, diameter = 11.5 cm), in front of the cylinder and allowed the dog to eat from it. One "leading trial" was then conducted in which the experimenter guided the dog to the open end of the cylinder by allowing them to follow a food lure into the opening of the cylinder. If a dog was cautious when approaching the bowl/apparatus in either of these warm-up trials or hesitant to put their snout into the opening of the cylinder during the leading trial, the dog was encouraged to get the treat and the trial was repeated until the dog would readily follow the food lure into the cylinder.

*Opaque cylinder trials.* Subsequently, dogs participated in five familiarization trials in which they watched the experimenter place a food reward inside the cylinder, then were released to access the food from the open end of the cylinder independently (without a lure). The open side of the cylinder was always on the dog's left (experimenter's right). This phase allowed dogs to repeatedly practice the behavior of accessing the treat inside the cylinder and helped ensure that the strategy to access the treat from the open side was fluent before the inhibitory control test trials (see below).

To prevent declines in motivation associated with failure to obtain a reward, if the dog touched the cylinder but did not obtain the food within 20 s, the experimenter guided them to the correct side and allowed them to eat the food from within the cylinder. If 20 s elapsed before the dog either successfully retrieved the food or contacted the apparatus, the trial was marked as "no response." Dogs were not guided to the treat following a "no response" trial, but instead participated in a "motivator trial," which for this stage of the task (opaque trials) was identical to the leading trial from warm-ups in which dogs follow a food lure into the opening. After the "motivator trial," the test trial on which the "no response" occurred was repeated. All scored responses reflected the dog's independent actions without the experimenter's assistance.

*Inhibitory control test trials.* These test trials were identical to opaque cylinder trials with the exception that the food reward was placed inside a transparent cylinder, allowing the subject to see the food reward through the front of the apparatus. A successful response (detouring to the open end of the cylinder) therefore required subjects to resist the prepotent response of approaching the visible food directly. Four test trials were performed. We recorded whether dogs touched the exterior of the cylinder with their snout or paw prior to accessing the food inside the cylinder. As before, if a dog touched the cylinder but did not access the food within 20 s, the experimenter guided them to the opening and allowed them to eat the food. If dogs did not access the reward or contact the apparatus within 20 s (“no response”, not scored), they were not guided to the food, but instead participated in a “motivator trial” (the experimenter bowl placed in front of the cylinder as in the first warm-up trial), followed by a repeat of the “no response” trial. If “no response” trials occurred four total times across the opaque trials and inhibitory control test trials, data collection for this task was discontinued ( $N = 4$  dogs across all timepoints).

*Dependent measure.* We used the proportion of trials in which dogs obtained the reward without first contacting the exterior of the cylinder in inhibitory control trials. Dogs who made responses on three or fewer inhibitory control trials were excluded from analysis ( $N = 3$  dogs across all timepoints).

## Sensory screen

Since older dogs may experience age-related hearing or vision loss, we conducted a brief sensory screening to assess responsiveness to visual and auditory stimuli. Failure on the vision screening was treated as an exclusion criterion given that all tasks required dogs to process visual stimuli. Failure on the auditory screening was not used as an exclusion criterion given that processing of auditory stimuli was not essential for task participation and these dogs would still attend to the experimenter’s movements and readily search for food when released. In the vision screening, the experimenter stood 1 m in front of the dog and dropped a cotton ball (25 cm diameter) from the dog’s eye level to the floor in front of the dog. The experimenter then knelt 1 m in front of the dog and 0.67 m to the side, and using a finger, flicked the cotton ball such that it passed in front of the dog from the dog’s left to right, and then repeated this procedure from the other side, flicking the cotton ball from the dog’s right to left visual field. The dog passed the vision screening if they followed the motion of the cotton ball with their head and/or eyes. All dogs passed the vision screening. The auditory screening consisted of an experimenter pressing a training clicker on the opposite side of their body from the dog such that the clicker was obscured from the dog’s view and approximately 0.33 m from the dog’s head. The dog passed the auditory screening if they showed an immediate (within ~1 s) observable response to the clicker on either side, including but not limited to a rapid change in head orientation or an ear flick on the side of the stimulus.  $N = 11$  dogs did not pass the auditory screening during one or more testing timepoints.

## Development of CANID from preliminary study

The battery presented by Hargrave et al. (2025) included five tasks that were administered across two study visits, each approximately 30–60 min. Our goal in developing CANID was to create an even shorter instrument that still robustly captured age-related cognitive differences in dogs. To do so, we retained the three tasks with the strongest associations with age in Hargrave et al. (2025) and made minor modifications to some tasks to enable more efficient administration, without compromising sensitivity to age-related variation.

In the Spatial Reversal task, we reduced the total number of trials from 30 to 20 based on retrospective exploratory analyses of data from Hargrave et al. (2025), which indicated that highly similar summary scores could be obtained using a reduced number of trials. Additionally, by using a lower trial cap we aimed to reduce potential for fatigue in older dogs who, relative to younger animals, typically require more trials to complete this task. Second, based on observations that some geriatric dogs failed to complete the baseline within 20 trials, a possible indication of profound cognitive impairment, we modified the scoring for this task to include data from baseline trials as an additional block in the summary score (previous scoring considered only subsequent reversal blocks,

**Table 2** Results of a linear mixed-effects model estimating the association between age and overall CANID score

| Predictor                       | Beta  | 95% CI      | p-value |
|---------------------------------|-------|-------------|---------|
| Timepoint                       |       |             |         |
| Baseline                        | —     | —           |         |
| 6-Month Retest                  | 0.23  | 0.10, 0.37  | <0.001  |
| 12-Month Retest                 | 0.04  | -0.10, 0.19 | 0.5     |
| Test Age (Years)                |       |             |         |
| 1st degree                      | -11   | -13, -8.9   | <0.001  |
| 2nd degree                      | -5.2  | -7.1, -3.3  | <0.001  |
| Sex                             |       |             |         |
| Female                          | —     | —           |         |
| Male                            | 0.07  | -0.11, 0.25 | 0.4     |
| Test Location                   |       |             |         |
| Arizona Canine Cognition Center | —     | —           |         |
| Canine Companions               | 0.65  | 0.36, 0.94  | <0.001  |
| Sit! Stay! Play!                | -0.07 | -0.26, 0.12 | 0.5     |

Abbreviation: CI = Confidence Interval

**Table 3** Repeatability metrics and pairwise ICCs for overall CANID score and individual CANID tasks. 95% confidence intervals are provided in square brackets

|                  | Adjusted ICC      | Intercept-Only ICC | Baseline/6-Month ICC | Baseline/12-Month ICC | 6-Month/12-Month ICC |
|------------------|-------------------|--------------------|----------------------|-----------------------|----------------------|
| Overall Score    | 0.45 [0.29, 0.58] | 0.63 [0.49, 0.74]  | 0.63 [0.51, 0.72]    | 0.59 [0.47, 0.70]     | 0.57 [0.42, 0.69]    |
| Spatial Reversal | 0.29 [0.12, 0.47] | 0.43 [0.26, 0.58]  | 0.41 [0.26, 0.54]    | 0.52 [0.37, 0.63]     | 0.38 [0.19, 0.54]    |
| Delayed Search   | 0.45 [0.29, 0.61] | 0.51 [0.34, 0.64]  | 0.51 [0.38, 0.62]    | 0.47 [0.32, 0.59]     | 0.57 [0.42, 0.69]    |
| Cylinder         | 0.46 [0.28, 0.59] | 0.53 [0.34, 0.66]  | 0.59 [0.48, 0.69]    | 0.36 [0.19, 0.50]     | 0.48 [0.31, 0.62]    |

not the baseline block, when calculating the total number of blocks completed and the number of trials in the longest block).

The Cylinder task was modified to eliminate the reversal phase described in Hargrave et al. (2025). This change reduced the overall length of the Cylinder task and was informed by exploratory analyses which revealed stronger age associations on the inhibitory control trials preceding the reversal component of the task.

The Delayed Search task was retained from Hargrave et al. (2025) without modification.

Because the modifications described above only involved a shortening (reduction of total trial numbers, or elimination of later task stages) of procedures described by Hargrave et al. (2025), it was possible to rescore data collected under the original procedures using the updated CANID scoring protocol.

For a summary of task changes from Hargrave et al. (2025), see ESM Table 2.

## Availability of CANID methods manual and resources

To facilitate and encourage use of CANID by other researchers, we developed a detailed guide to implementing these protocols, including a comprehensive methods manual, video library, data collection tools, and code for scoring and analysis. These materials are available in an OSF repository (<https://osf.io/n7jt9/overview>).

## Repeat testing

Baseline CANID scores were obtained at dogs' initial study visits. To assess retest reliability and potential practice effects, a subset of dogs underwent repeat testing at six and twelve months following baseline at the same test location as their baseline visit (with few exceptions – 3 dogs originally tested at Sit! Stay! Play! experienced at least one follow-up timepoint at the Arizona Canine Cognition Center). These intervals were selected to assess the relevance of CANID for longitudinal studies of aging, in which follow-up visits would likely occur semi-annually or annually. Ninety-one dogs have data for all three study timepoints (see ESM Table 3 for details). Dogs

missed one or both follow-up visits for a variety of reasons, including dog mortality, the family relocating out of the area, owner non-response, or scheduling conflicts that prevented testing within the target follow-up window. Follow-up patterns were also influenced by site-specific logistical factors. At Canine Companions, staffing limitations precluded six-month retesting for most dogs. At Sit! Stay! Play!, dogs were not routinely followed if they discontinued daycare attendance because we aimed to maintain a consistent testing location within subjects. Finally, because enrollment was ongoing, some dogs who joined later in the study had not yet reached their scheduled six- or twelve-month follow-up period by the time the dataset was finalized for the present analyses.

## Statistical analysis

Analyses were performed using R Statistical Software (R Core Team 2025). To assess inter-rater reliability, a second rater coded a randomly selected  $\geq 20\%$  of trials. Inter-rater reliability (Cohen's Kappa) was excellent for all variables used in scoring (ESM Table 5).

Our statistical models made use of two types of summary scores, generated using the procedures from Hargrave et al. 2025 and described below. Using all baseline data, we first generated task-level summary scores for each subject, reflecting their overall performance on a specific task. We then generated overall CANID summary scores, which provide an aggregate measure of performance across the different tasks. The Spatial Reversal and Delayed Search task scores were derived from principal components analyses with the dependent measures for each task as the input data and scores on the first component used as the task summary score. The Cylinder score did not require this approach as it was a single measure (proportion correct). To generate overall (cross-task) summary scores we used a similar approach incorporating task-level summary scores as the input data, and component scores from the first component as an overall CANID score. We standardized task and overall scores before performing statistical analyses, including applying a Yeo-Johnson transformation to Spatial Reversal and Delayed Search task scores to normalize their distributions.

To generate task scores and overall CANID scores for data from follow-up timepoints, we used the predict() function from the psych package (William Revelle 2025) to project data from six- and twelve-month retests into the same principal component space defined using baseline data.

For dogs missing a single task summary score (due to aborting the entire task or having insufficient task data:  $N = 10$  dogs at baseline, 1 at 6-month retest, and 3 at 12-month retest), we imputed their score on the missing task when generating overall CANID scores but did not include imputed data when analyzing task-specific repeatability and practice effects. Imputation used the linear regression-based method 'norm.predict' from the mice package (Buuren & Groothuis-Oudshoorn 2011) with the observed task scores and test location as predictors. For dogs with missing data on more than one task (6 dogs at baseline), we did not generate an overall CANID score.

To assess the effect of repeated test administration and the association between age and cognitive score, we fit linear mixed-effects models using the lme4 package (Bates et al. 2015) with fixed effects for dog age at test (modelled using a second-degree orthogonal polynomial to accommodate non-linear age effects), follow-up timepoint (e.g., baseline, 6-month, 1-year), sex, and test location, and a random effect for dog ID. Models were fit for both the overall CANID score and separately for each of the three individual tasks (Spatial Reversal, Delayed Search, Cylinder).

As estimates of repeatability, we report bivariate intraclass correlation coefficients between timepoints as well as adjusted ICC values from mixed models incorporating effects for age and other covariates and ICC from an unadjusted (intercept-only) model, comparable to R (repeatability) which has been reported in other animal cognition and behavior studies (Table 3).

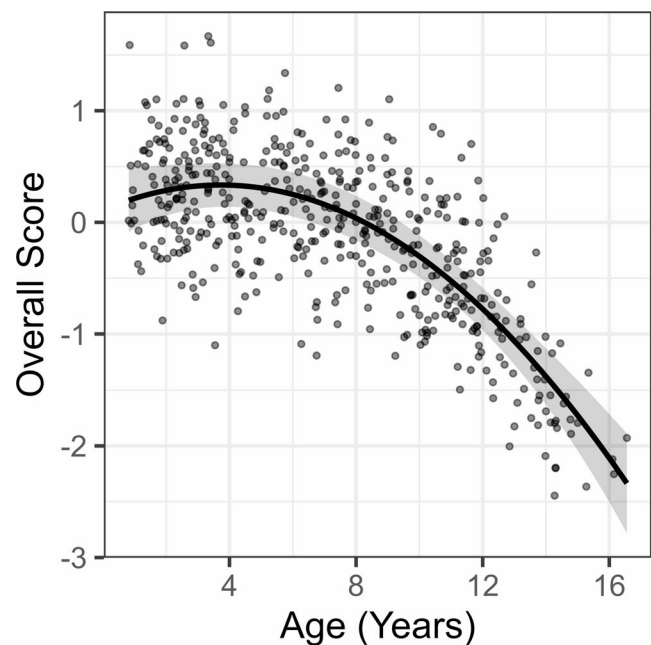
## Results

Scores on all three tasks loaded positively on a single component (Spatial Reversal: 0.81, Delayed Search: 0.64, Cylinder: 0.69) that explained 51.2% of variation. We used scores on this component as the overall CANID score. Details regarding raw measures for the three component tasks are presented in supplemental material (ESM Table 6 and 7).

Age accounted for 27% of the variance in overall scores (partial  $R^2 = 0.27$ ), corresponding to a large effect (Cohen's  $f^2 = 0.43$ ; see Fig. 2 and Table 2). A likelihood ratio test comparing models with and without age (modeled as a second-degree polynomial), indicated that age significantly improved model fit ( $\chi^2(2) = 114.79$ ,  $p < 0.001$ ). The model-based adjusted ICC for overall CANID scores was 0.45, indicating moderate repeatability when accounting for age. Pairwise ICCs between timepoints and ICC from an unadjusted (intercept-only) model were higher (Fig. 3, Table 3), which suggests that some within-individual consistency is attributable to strong, systematic age effects rather than individual differences that are independent of age. Modest improvements in overall scores were evident at the six-month ( $b = 0.23$ , 95% CI [0.10, 0.37]) but not twelve-month retest ( $b = 0.04$ , 95% CI [-0.10, 0.19]).

There were significant effects of both the first- and second-order age terms for all individual tasks (ESM Fig. 1, ESM Tables 8–10). The effect of timepoint on score varied by task. We observed improvement in Spatial Reversal scores at the six-month retest ( $b = 0.20$ , 95% CI [0.03, 0.37]), but not the twelve-month retest ( $b = 0.02$ , 95% CI [-0.16, 0.21]). Dogs' scores on the Delayed Search task were similar to baseline at the six-month retest ( $b = 0.01$ , 95% CI [-0.14, 0.16]) but lower at the twelve-month retest ( $b = -0.24$ , 95% CI [-0.41, -0.08]). On the other hand, a slight but enduring improvement was observed for the Cylinder task at the six-month retest with these performance gains maintained at the twelve-month retest ( $b = 0.28$ , 95% CI [0.13, 0.44]). Repeatability as assessed by ICCs from an intercept-only model (i.e., without accounting for age effects) for all tasks was high relative to previously reported repeatability in animal cognition (Cauchoix et al. 2018) (Table 3, ESM Fig. 2).

**Fig. 2** Relationship between age and overall CANID scores estimated from a linear mixed-effects model. Points reflect partial residuals from the mixed model (adjusted for all model terms except age). The gray shaded region represents the 95% confidence interval. Data points come from  $N = 233$  dogs contributing 485 observations (6/239 dogs contributed data for only one task and were thus not given an overall score – see [Statistical Analysis](#))



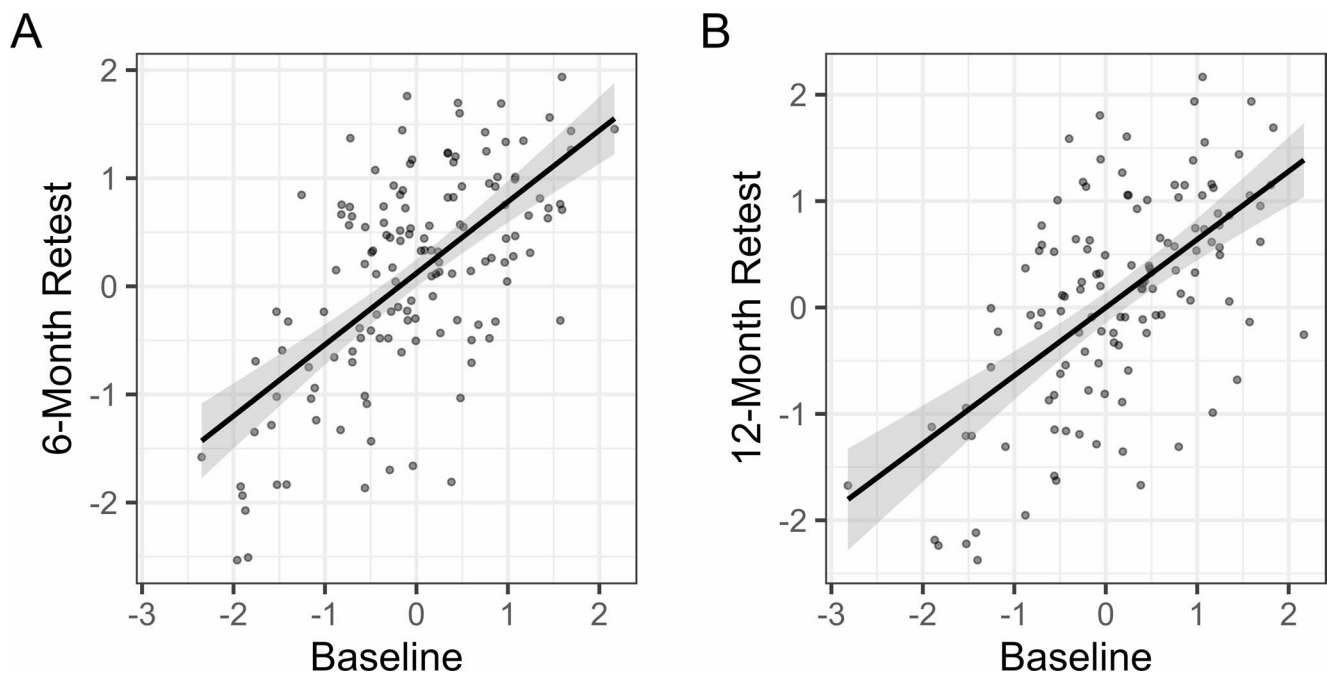


**Fig. 3** Repeatability of overall CANID scores at **A**) 6 months compared to baseline (N = 138) and **B**) 1 year compared to baseline (N = 114). Shaded regions indicate 95% confidence intervals

## Discussion

In this study, we introduced the Cognitive Assessment for Neuropsychological Impairments in Dogs (CANID) and assessed its suitability for longitudinal aging research by measuring test–retest reliability, practice effects, and sensitivity to age-related cognitive differences. We found that overall CANID scores, as well as scores on all three of the underlying subtests, have robust negative associations with age and that these scores are repeatable across 6- and 12-month periods, with a modest, short-term improvement at 6 months that was not observed at 12 months. Measures used in task scoring have excellent interrater reliability (ESM Table 5) indicating strong to near-perfect agreement (McHugh 2012). The combination of sensitivity to age-related differences in cognitive performance, temporal repeatability, high interrater reliability, minimal practice effects with repeated task exposure, and efficient administration format makes CANID a robust and promising tool for longitudinal studies of cognitive aging in dogs.

An important element of the current study was measurement of test–retest reliability at 6- and 12-month intervals. Because there are many ways in which researchers estimate repeatability of cognitive and behavioral measures, direct comparisons across studies can be challenging. However, the repeatability of overall CANID scores exceeds meta-analytic estimates of behavioral/personality consistency in nonhuman animals, even when controlling for variation explained by age, which studies not focused on aging seldom address. Fratkin et al. (2013) reported a mean  $r$  of 0.43 for repeatability of personality measures in dogs, while Cauchoux et al. (2018) found that across a broad range of taxa, the mean adjusted  $R$  for repeatability of cognitive task performance was 0.28. CANID's repeatability also approximates retest reliability estimates for human neuropsychological measures ( $r \sim 0.7$ , Calamia et al. 2013). Furthermore, while some studies report that repeatability differs by task type (Ashton et al. 2022; Junttila et al. 2024), all three CANID tasks exhibited substantial repeatability (Table 3).

Alongside evaluating repeatability of CANID scores, we aimed to assess mean differences in scores across time, which may arise due to practice effects, cognitive decline, or a combination thereof. Analyses of temporal changes revealed mixed patterns across tasks with, relative to baseline, higher follow-up scores on the cylinder task at six and twelve months, higher follow-up scores on the spatial reversal task at six months, and lower

follow-up scores on delayed search at twelve months. Overall CANID scores were moderately higher than baseline at 6-month follow-up but this effect was not observed at 12-month follow-up. These patterns may reflect a combination of practice effects and cognitive decline.

Practice effects are normal and expected in many cognitive tests. We observed small overall performance gains at the six-month retest that appeared to attenuate by twelve months, such that the twelve-month retest scores were not statistically different from baseline. At the six-month retest, dogs' overall scores improved on average +0.23 standard deviations from baseline, a magnitude comparable to the average retest gains of ~0.24 standard deviations found in a large meta-analysis of human cognitive tests (Calamia et al. 2012). The improvement in overall CANID scores is driven by higher Spatial Reversal scores at six months, which drop back to baseline levels at twelve months, and a slight but enduring performance boost in the Cylinder task (ESM Table 10). Specifically, dogs' raw cylinder scores at six- and twelve-month retests averaged 9 percentage points higher than baseline. The sustained improvement seen in the Cylinder task merits closer consideration, given its persistence and the existing literature on repeat exposure to this and similar inhibitory control tasks.

It is possible that this increase in Cylinder performance after baseline, which is maintained at twelve months, reflects increased experience with retrieving a reward from a transparent barrier after dogs' first exposure to this task. Indeed, as animals in transparent detour-reaching tasks gain additional experience that these barriers are solid and impenetrable, their performance can improve (van Horik et al. 2018). In dogs, cylinder scores improve in a developmental fashion throughout puppyhood (Salomons et al. 2026) and from puppyhood to adulthood (Bray et al. 2021; Lazarowski et al. 2020). Practice effects, in which naïve individuals perform worse than those with prior task experience, have also been documented *within* puppies (Salomons et al. 2026) and from puppyhood to adulthood (Junttila et al. 2025). Junttila et al. (2025) found that adults that were previously tested on the cylinder task as puppies outperformed naïve adults despite a long gap (median 1.7 years) between puppy and adult testing. However, current evidence on practice effects in the cylinder task is mixed, and some studies do not show improved performance with repeat exposure. In a small sample of adult dogs, Olsen (2022) observed no effect of repeated testing on the cylinder task over a two-week interval. Likewise, Montgomery et al. (2026) found that a subset of dogs with prior experience in the cylinder task did not perform better than naïve dogs encountering it for the first time. In a study by Simon et al. (2025), elderly dogs with at least some level of cognitive impairment showed no significant improvement in cylinder scores, but rather stability over six months with 2–4 task exposures during that period. Although an absence of practice effects is also reported in younger dogs in some of the aforementioned studies, the advanced ages of dogs in Simon et al. (2025) could reduce the opportunity for improvement. In human neuropsychological testing, older individuals show smaller practice effects than younger individuals (Calamia et al. 2012) and while some practice effects are observed in Alzheimer's and MCI patients (Goldberg et al. 2015), in other cases they may lack practice effects altogether or exhibit less improvement with repeated exposure than healthy controls (Duff et al. 2024). While the canine cognitive test battery used by Bognár et al (2024) did not include a cylinder task, they note that young dogs' overall scores improved more longitudinally than those of old dogs, potentially due to greater cognitive plasticity in young dogs allowing for more learning from prior participation to occur. This is corroborated by evidence from laboratory beagles, in which young dogs appear to benefit more from prior cognitive task participation than old dogs when faced with a discrimination learning task (Milgram 2003). Jointly, the canine and human literature on practice effects implies that improvement with repeated testing may be reduced in a sample restricted to senior dogs or absent in dogs with Canine Cognitive Dysfunction (CCD). Whether this is the case in CANID remains to be investigated.

Decreases in performance were observed only for the delayed search task, consistent with the results of with Piotti et al. (2022), who in a similar spatial memory task found slightly reduced accuracy when dogs repeated the task after a two-week gap. We hypothesize that the decreased memory scores at 12 month follow-up in the current study may reflect cognitive decline, which is consistent with studies documenting cognitive decline over similar timescales using survey-based measures (Madari et al. 2015; Schütt et al. 2015). Overall CANID scores, however, did not decline over the same one-year follow-up period. We propose two potential explanations for this.

First, our data may not reflect substantive decline because our subjects' ages spanned the entire canine adult lifespan, with a large portion of young dogs who would not be expected to exhibit measurable declines within a year. Further, even among senior dogs, cognitive phenotypes exhibit considerable heterogeneity. Not all senior dogs develop cognitive impairment, and a substantial portion remain cognitively healthy even into old age (Salvin et al. 2010; Yarborough et al. 2022). In our mixed-age sample, senior dogs who are experiencing measurable decline within the study's 6–12 month follow period would therefore represent a fraction of the dogs old enough to potentially experience decline, further reducing our ability to detect population-level effects. Second, as discussed above, unlike owner-report CCD questionnaires, repeated cognitive testing is susceptible to practice effects, which may conceal cognitive decline.

Indeed, practice effects and age-related decline are not mutually exclusive. The observed short-term improvement in overall performance which then dissipates could be due to an initial practice effect that is then offset by aging-related decline by twelve months. This possibility is supported by evidence from studies in older human adults, in which practice effects may mask decline over time because the magnitude of practice effects can exceed that of longitudinal change (Salthouse 2010). Scores may appear at first to be stable or improving, but after adjusting for practice effects, decline becomes apparent (Sanderson-Cimino et al. 2023). In this study, we have defined a practice effect as improved performance upon retesting. Critically, however, practice effects can manifest as improved, stable, or even declining overall performance because longitudinal change and practice effects can be present simultaneously and to varying degrees. Performance that appears stable, for instance, could be the result of approximately equal magnitudes of improvement due to repeat exposure and decline which effectively cancel out. While beyond the scope of the present analysis, explicitly modeling and adjusting for practice effects would hold value for future research. As future studies investigate cognitive decline using CANID it will also be critical to perform moderation analyses, in which the effects of time are allowed to vary in relation to dog age, given that decline is expected in older but not younger dogs.

Finally, we found a significant effect of test location on performance after controlling for important covariates such as age. Specifically, dogs tested at Canine Companions performed better than those tested at an on-campus research center or at a dog daycare (Table 2). These differences appear to be driven by significantly better performance on tasks requiring inhibition: Cylinder (motor inhibition of prepotent response) and Spatial Reversal (suppression of previously learned spatial response) (ESM Tables 8 and 10). In contrast, while no overall score differences were observed for dogs tested at Sit! Stay! Play!, these dogs performed slightly, but significantly, worse on the Cylinder task compared to dogs tested at the Arizona Canine Cognition Center (ESM Table 10), potentially reflecting the influence of a higher arousal testing environment which can negatively affect inhibitory control. In this sample, dogs tested at Canine Companions predominantly represent dogs who 1) began service dog training but who were released from the program, 2) underwent some service dog training and became part of the organization's breeding program, or 3) were retired or actively working service dogs at the time of testing. Thus, the better performance observed in this group could relate to temperament differences, such as lower baseline arousal, which is known to influence executive function in dogs (Bray et al. 2015), training history (Bray et al. 2023), which was likely more extensive for these dogs compared to others in our sample, or the relative genetic homogeneity of a group of dogs bred for behavioral and health traits suitable for assistance dog work. While some studies show benefits of training and cognitive stimulation for cognitive functioning in older dogs (Bray et al. 2023; Chapagain, Virányi, et al., 2017; Milgram et al. 2006), others find no effect (Chapagain et al. 2020). The concept of cognitive reserve and its protective effects with respect to cognitive aging are well-documented in humans (Nelson et al. 2021; Opdebeeck et al. 2016; Pettigrew & Soldan 2019). Future research should further examine whether factors such as training history and lifetime cognitive enrichment (both potentially analogous to ways cognitive reserve is quantified in humans) could prevent or slow cognitive aging in dogs.

Neuropsychological assessments such as CANID have several potential drawbacks. Although CANID testing can be completed in an hour or less, much more rapidly than lengthy operant protocols requiring weeks to months of training, it remains more time and resource intensive than deploying questionnaires to dog owners, making it inherently less scalable. It also requires dogs who are sufficiently motivated to obtain food rewards and are not

fearful of the testing environment or unfamiliar people. Relatedly, severe cognitive dysfunction may preclude participation in some cognitive tasks. Fefer et al. (2022) performed cognitive testing using a variety of tasks in aged pet dogs, many of whom had some level of cognitive dysfunction, and most dogs participated successfully. However, they noted that some dogs with CCD were unable to complete any of the cognitive tasks. Difficulty implementing cognitive testing in dogs with severe CCD could be due to deficits in cognition that render them unable to perform the tasks, but it could also be due in part to other characteristics such as fear, anxiety, and decreased appetite, all of which are associated with CCD (Fisher et al. 2026). In a food-searching task implemented by González-Martínez et al. (2013), a minority of severely cognitively impaired dogs who were tested ever attempted to search for food or were able to obtain the food in a problem-solving task. It is unclear whether the reason for this is a cognitive inability to locate the food or related to motivational differences such as lower food motivation in severely affected dogs, but cumulatively, existing evidence indicates that cognitive testing involving active participation for food rewards may be most feasible and appropriate before dogs reach a stage of severe cognitive impairment. Another potential disadvantage of cognitive testing relative to questionnaires is that in longitudinal designs, repeated exposure to the same tasks can introduce practice effects, as discussed above. It is also likely that cognitive testing scores are less stable than questionnaire-based evaluations. Unlike questionnaires, which ask dog owners to aggregate the frequency of various dog behaviors over a recent span of daily life, cognitive testing is completed in a single hour on a single day and is thus vulnerable to day-to-day fluctuations in dogs' internal states. Nonetheless, there is emerging evidence that cognitive tasks may serve as a more objective measurement in clinical trials than questionnaires, which are inherently subjective and can be prone to placebo effects (Simon et al. 2025). Questionnaires may also be less sensitive to early stages of decline (Chapagain et al. 2017a, b).

As both formal cognitive testing and questionnaires have strengths and disadvantages, comprehensive approaches combining both have been highlighted as a key priority in the study of cognitive aging in companion dogs (Chapagain et al. 2017a, b). Several other researchers have demonstrated correlations between cognitive-behavioral measures and biomarkers or other measures of cognitive status in dogs. For example, in laboratory beagles, beta-amyloid deposition relates to impaired discrimination and reversal learning as well as spatial learning (Cummings et al. 1996), and brain atrophy, particularly in the frontal lobe, is correlated with poorer performance on inhibitory control and working memory tasks (Tapp et al. 2004). In pet dogs, a variety of tasks, including measures of food searching, sustained gaze duration, and cylinder task performance correlate with questionnaire-based measures of CCD severity (Fefer et al. 2022; González-Martínez et al. 2013). Additionally, Fefer et al. (2022) found that cylinder performance correlates with plasma neurofilament light chain concentration, a biomarker of neurodegeneration. As the present study does not involve questionnaires or biological samples, future research should explore additional aspects of validity, such as whether CANID scores agree with other measures of cognitive dysfunction. Doing so can be a way of assessing both construct validity, specifically convergent validity (i.e., agreement between CANID and other, typically questionnaire-based scales) and ecological validity (i.e., how owner-reported measures of a dog's cognitive function in daily life compare to a dog's CANID score). Because studies in both companion and laboratory dogs suggest that CCD is preceded by a stage of mild cognitive impairment (Madari et al. 2015; Schütt et al. 2015; Studzinski et al. 2006), it is possible that CANID scores could be predictive of dogs' future scores on established CCD scales rather than convergent with concurrent CCD status. Longer term studies using CANID accompanied by cognitive dysfunction questionnaires, biomarkers, and/or veterinary diagnostics are needed to address this question. CANID detects age-associated differences beginning in mid-life, earlier than the typical ages at which signs of CCD appear (Madari et al. 2015; Neilson et al. 2001; Salvin et al. 2010), supporting the possibility that CANID may detect preclinical decline. Future work may also combine CANID with CCD assessments to help uncover if CANID can differentiate normal cognitive aging from pathological cognitive decline. While CCD can appear as early as 8 years of age, dogs affected at such early ages typically display only mild signs which may be overlooked by owners who perceive these as normal age-related changes rather than an early stage of cognitive decline (Madari et al. 2015; Olby et al. 2026). In CANID, age-related effects are apparent beginning around 8 years, whereas in questionnaire-based

assessments of CCD, the probability of exceeding the diagnostic threshold does not increase sharply until an inflection point at approximately 10–12 years (Bray et al. 2023; Salvin et al. 2010; Yarborough et al. 2022). If CANID is capable of detecting earlier and subtler signs of impairment, it could serve as a powerful tool for evaluating the effects of lifestyle, environmental, and genetic factors on cognitive aging, and for assessing responses to pharmacological, dietary, or behavioral interventions designed to prolong cognitive health.

Another direction for future research will be to assess CANID's ability to detect within-individual change across aging, particularly in senior dogs. We observed that scores within 12 months of baseline testing were largely stable in a mixed-age population. Following dogs over longer periods and modeling longitudinal changes in relation to age will be critical for assessing CANID's suitability for measuring cognitive decline. Additionally, if CANID is to be used in clinical studies where individual outcomes are of interest, it will be important to determine whether an individual is declining beyond what can be expected by measurement error, so important benchmarks such as minimum detectable change should be established. Together, these next steps will help to further establish CANID, and cognitive testing more generally, as a reliable tool in canine cognitive aging research.

In developing CANID, our goal was not only to create a sensitive and efficient tool for assessing cognitive aging in companion dogs, but also to make this tool broadly accessible to the research community. To facilitate replication and adoption, we have made all materials publicly available, including a detailed methods manual, apparatus specifications, training videos, standardized data sheets, and R code for scoring (<https://osf.io/n7jt9/overview>). By lowering logistical and methodological barriers, we hope CANID can be readily implemented across laboratories and in diverse studies focused on cognitive aging in dogs. Widespread use of a shared, open, and standardized functional assessment will enable more direct comparisons across studies, accelerate discovery, and ultimately strengthen our capacity to understand and intervene in cognitive aging.

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**Data availability** Data used in this manuscript, and accompanying code for analysis, can be found in the project's OSF repository (<https://osf.io/n7jt9/overview>).

## Declarations

**Conflict of interest** Daniel Promislow is a consultant for WndrHLTH.

**Statement of animal ethics** All procedures were approved by the University of Arizona Institutional Animal Care and Use Committee (protocol #16–175) and we obtained written consent from all owners of participating dogs. If dogs became fearful or anxious during testing and were not easily soothed, data collection was discontinued. No data collection occurred if dogs were fearful or anxious upon arrival and unable to acclimate within approximately fifteen minutes.

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