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Growing old gracefully—Behavioral changes associated with "successful aging" in the dog, *Canis familiaris*

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Abstract Aging is associated with behavioral and cognitive changes in all mammals. Unlike most clinical presentations, changes associated with aging do not always reflect an underlying pathology and therefore baselines for normality can be difficult to establish. Using data from a large cross-sectional survey of older dog owners, we aimed to identify normative behavioral changes associated with "successful aging" in dogs, and the rate of deterioration that could be expected over a 6-month period. Binary logistic regression identified significant age group effects from 18 items (difference in reported item incidence across age group: 4.5%-30.3%, $P < 0.001$-0.038). Significant age group effects on the percentage of dogs deteriorating over the preceding 6 months were evident in 21 items (difference in item deterioration across age group: 3.5%-25.7%, $P < 0.001$-0.033). The modal frequency of problem behaviors and abnormal ingestive or locomotory items was found to be low and the effect on memory and learning was minimal. Despite this, more than half of the items were reported to have shown a greater than 10% incidence of deterioration. In particular, activity and play levels, response to commands, and fears and phobias showed considerable deterioration. These findings represent the first steps toward the development of baseline values for normal behavioral changes in "successfully aging" dogs.

Introduction

Behavioral changes accompany almost all clinical presentations of injury or illness in dogs. Limping is a change in locomotory behavior and a dog that is in pain may show a lowered bite inhibition. Such abnormal behaviors are easy to characterize, but it is much more difficult to delineate behavioral changes that occur in the absence of obvious disease, such as those associated with aging. In all mammals (Berchtold and Cotman, 2009), aging has been associated with physical and cognitive changes that often blur the line between normal and diseased states. Research has shown that cognitive aging in dogs, similar to human beings, can be divided into successful aging, mild cognitive impairment, and cognitive dysfunction or dementia (Adams, 2000a). However, in cases of aging, an absence

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of behavioral change cannot be used to distinguish healthy from diseased animals because even "successful aging" results in some cognitive decline and behavioral changes. Rather, the opposite seems to occur, in that dogs with canine cognitive dysfunction (CCD) often remain undiagnosed because owners conflate neurodegenerative changes with *bona fide* normative age-related change (Landsberg and Araujo, 2005; Salvin et al., 2010). "Successful aging" can therefore be considered as a rate of cognitive deterioration that does not affect the day-to-day functioning of the individual.

Although attitudes toward dogs as an ethological subject have improved over the past few decades (Houpt, 1983; Davenport and Davenport, 1990; Neff and Rine, 2006), only a moderate number of studies have examined the interaction between aging and various ethological domains and there remains no cohesive overview. This represents an important gap in the canine literature and may limit the extent to which all reports of adult dogs in the community can be generalized. Ingestive behavior is known to be influenced by age (Laflamme, 2005), and hyperphagia (in the absence of obesity), in particular, is known to influence longevity and increase the development of age-related degenerative disease (Lawler et al., 2008). Locomotory behavior (Head et al., 1997; Siwak et al., 2001) and human–dog interactions (Head et al., 1997; Salman et al., 2000; Siwak et al., 2001; Baranyiova et al., 2004; Marinelli et al., 2007) have also been shown to be age sensitive.

By contrast, learning and memory in the aged laboratory dog have been extensively studied. Visuospatial working memory has been shown to be 3-fold lower and the number of learning errors has been shown to increase significantly in aged versus young dogs (Adams et al., 2000b). Cognitively impaired versus unimpaired aged dogs also show lower accuracies in a range of laboratory-based delayed non-match to position tests (Head et al., 1995), although, in this particular study, cognitively unimpaired aged dogs did not differ from young dogs. Investigations into the effect of age on a dog's executive function have produced similar results. Tapp et al. (2003) found that aged dogs made more errors on a reversal learning task than young dogs, whereas dogs older than 11 years of age showed marked perseverance and inability to suppress previously learnt responses. Interestingly, studies have reported no age-related impairment in discrimination learning and memory (Landsberg and Araujo, 2005), suggesting that aging preferentially affects some cognitive functions above others. Although these studies clearly demonstrate the presence of age-related deficits, the manifestation of these deficits outside of the laboratory context remains unclear. This makes it difficult for the owner or veterinarian to extrapolate laboratory findings to the behavioral changes observed in dogs in the community. A study of "successful" canine aging behavior has the potential to facilitate our understanding of canine medicine by establishing realistic baselines for behavioral changes that reflect a normal consequence of the aging process.

To identify the behavioral profile or ethogram of "successfully aging" companion dogs, and thus delineate what should be considered "normal," it is first important to exclude all animals suspected of having CCD and then to identify those behavioral attributes that are susceptible to age-related change. Our aim was to analyze data from a large epidemiological study to identify the behavioral characteristics of "successfully aging" dogs. After dogs with a behavioral profile consistent with CCD were excluded, information about a variety of ingestive, locomotory, cognitive, and problem behavior items was analyzed for changes that accompanied aging. Data on the frequency and types of dog–owner interactions were also collected.

Materials and methods

Senior dog survey

The senior dog survey (SDS) consisted of 83 items encompassing dog and owner details, general management practices and health, eating and drinking, activity levels, dog–owner interactions, problem behaviors (including aggression and house soiling tendencies), and fears and phobias. Items were developed with reference to previously published cognito-behavioral scales in both human beings (Hughes et al., 1982) and dogs (Colle et al., 2000; Landsberg et al., 2003; Pugliese et al., 2005) and in consultation with veterinary and behavioral experts. Each item comprised 2 parts, the first quantified the frequency or severity of a particular item and the second determined the level of change in that item over a 6-month period. Questions on response frequency/severity were scored from 1 (least) to 5 (most), with a descriptor for each numeric score. Similarly, questions on the change in response were also scored from 1 to 5, with much less severe/frequent scoring 1, the same or no change scoring 3, and much more severe/frequent scoring 5. Further details on the scoring options for each question can be seen in the online supplementary copy of the SDS.

The SDS was distributed in both online and hardcopy formats, with owners of dogs aged ≥ 8 years being invited to participate. An accompanying e-mail message was disseminated to all veterinary colleges in Australia, New Zealand, the United Kingdom, and North America. The message was a request to these colleges to distribute the survey link to their staff and students. A dog forum (www.dogzonline.com.au) and the Association of Pet Dog Trainers (Australia) Web site also displayed a link to the SDS for their members. A hardcopy version of the survey was distributed to more than 92,000 readers in Australia and New Zealand through *DogsLife* Magazine (Issue 86, November/December 2007).

Statistical analysis

SPSS v.17 (SPSS Inc, IBM NY) was used for all statistical analyses and the significance threshold was maintained at 0.05. Responses for those subsections with low numbers of positive responses, including aggression (positive responses = 20%-29%), house soiling (positive responses = 23%-24%), and change in fears/phobias (positive responses = 32%-35%), were pooled to form an overall summary score for each subsection. Dogs with a veterinary diagnosis of cognitive dysfunction (CCD; n = 18) or neurological disease (n = 23) were excluded from the cohort. An additional subsample (n = 97) of dogs were excluded because they had a neurobehavioral profile consistent with CCD based on classification using the recently described CCD rating scale (Salvin et al., 2011). The CCD rating scale was derived from the aforementioned SDS, by isolating a subset of items that distinguished between CCD and successfully aging dogs with an overall accuracy of 98.9% (positive predictive value = 77.8%, negative predictive value = 99.3%).

All behavioral items were clustered into 2 categories. Items relating to the change in the frequency or severity of a response were separated into category 1, "the response had stayed the same or improved"; or category 2, "the response had deteriorated." In most instances, items reporting the frequency or severity of a response were separated into category A, "never displays that response"; or B, "sometimes displays that response." Exceptions to this are outlined in Table 1. Reported age was also categorized, forming 3 groups: $\leq$10 years (n = 253), 10-12 years (n = 275), and >12 years (n = 263). These age categories were selected because they separated the cohort into 3 approximately equal groups. Binary logistic regression was used to identify any effects of age for each item. The mode of each item and the percentage of the cohort that reported deterioration in a dog's response were used to generate the behavioral profile of "successfully aging" dogs.

Results

Sample characteristics

Sample characteristics have been reported in detail elsewhere (Salvin et al., 2010). In brief, a total of 1,100 surveys from 11 countries were obtained, of which 957 were eligible for inclusion. Within this sample, 826 dogs (86.3%) were classified as "successfully aging" and data from these dogs are the subject of the current report. The majority of responses were from Australia (n = 428), the United States of America (n = 299), New Zealand (n = 45), and the United Kingdom (n = 35).

A total of 651 purebred dogs were represented covering >100 breeds. The 5 most commonly reported breeds were Border Collie (n = 58), Labrador (n = 47), Golden Retriever (n = 44), German Shepherd (n = 37), and Shetland Sheepdog (n = 19). In all, 175 crossbred dogs were also represented. Female dogs slightly outnumbered male dogs, with 55% of the sample being female (6.2% entire, 93.8% desexed) and 45% male (14.9% entire, 85.1% desexed).

Behavioral profile of "successful aging" dogs

Table 2 shows the behavioral profile of "successfully aging" dogs and the proportion of dogs showing deterioration over the past 6 months.

Effects of age group on behavior frequency

Eighteen items changed significantly ($P < 0.05$) with age group. Of these, 8 showed an increase in their frequency (Figure 1), whereas 8 others showed a decrease (Figure 2). Two others, oral behavior toward others and vocalizing at no stimuli apparent to the owners, showed an inverted U-shaped distribution across age group

Table 1 Classification of atypical frequency of response categories used in the binary regression analysis of successfully aging dogs

	Response category for binary regression analysis	
Response	A	B
Time spent eating per day	10 minutes or less	More than 10 minutes
Still hungry after a meal	Once a month or more	Never
Time spent chewing	Once a week or more	Once a month or less
Time spent active per day	More than 2 hours	2 hours or less
Percentage of active time spent playing	More than 30% of the time	30% of the time or less
Excitement for walks	More than 90% of the time	90% of the time or less
Number of wakes during the night	1-5 times or less	5-10 times or more
Time spent in contact or close proximity to owner	90% of the time or less	More than 90% of the time
Enthusiastic to greet returning owner	More than 90% of the time	90% of the time or less
Responds immediately to verbal commands	More than 60% of the time	Less than 60% of the time
Displays breed-typical behaviors	More than once a fortnight	Once a month or less
Time taken to learn new tasks	Fewer than 8 attempts	8 attempts or more

Table 2 The most commonly reported frequency for each response and the percentage of surveyed dogs (n = 826) that showed deterioration in that response over the previous 6 months

Response	Frequency (mode)	Deterioration (%)
Ingestive behaviors		
Time spent eating per day	5-10 minutes	15
Still hungry after a meal	Daily	5.4 (decrease)
Fails to finish a meal	Never	9.7
Time spent chewing (toys and bones)	Once a week	18.4 (decrease)
Amount drunk per day	NA[a]	20.8
Stands over bowl but doesn't drink	Never	2.1
Locomotory and arousal behaviors		
Time spent active per day	0-2 hours	40.1 (decrease)
Percentage of active time spent playing	1%-30% of the time	26.5 (decrease)
Excitement for walks	>90% of the time	11.7 (decrease)
Number of wakes during the night	1-5 times	18.4
Pacing, circling, or wandering without purpose (abnormal locomotion)	Never	12.3
Human–dog interactions		
Time spent in contact or close proximity to owner	60%-90% of the time	11.9
Oral behavior (licking and nibbling) directed at other pets or people	Never	3.4
Avoids contact or petting	Never	7.4
Enthusiastic to greet returning owner	>90% of the time	9.8 (decrease)
Memory and learning		
Stares blankly at the walls or floor	Never	8.2
Failure to recognize familiar people	Never	6.9
Responds immediately to verbal commands	60%-90% of the time	28.3 (decrease)
Displays breed-typical behaviors	Daily	15.4 (decrease)
Time taken to learn new tasks	3-5 attempts	17.4
Gets stuck behind objects or furniture	Never	6.9
Walks into walls or doors	Never	5.7
Goes to the hinge side of the door to be let out	Never	2.8
Difficulty finding dropped food	Never	16.5
Fails to shake when wet	Never	2.7
Problem behaviors		
Oral behavior (licking and nibbling) directed at objects	Never	4.8
Vocalizes at no apparent stimuli	Never	16.7
Aggression	None	10.4
House soils	No	15.5
Fears/phobias	No	21.8

Unless specified otherwise, a deterioration is defined here as an increase in the frequency or severity of the response.
[a]There is no modal frequency for amount drunk per day because this item is dependent on the size of the dog.

(Figure 1), with the frequency of behavior at 10-12 years being higher than that at both <10 years and >12 years.

Effect of age group on behavioral change

Nine ingestive, arousal, and locomotory items showed a significant ($P < 0.05$) increase with age group in the percentage of dogs that showed a reported deterioration in that item over the preceding 6 months (Figure 3). Nine items relating to learning and memory also showed a significant increase with age group in the percentage of dogs reportedly deteriorating over the preceding 6 months (Figure 4). Of items that related to problem behaviors, only 3 showed a significant increase with age group in the reported incidence of dogs deteriorating (Figure 5).

Discussion

The behavioral changes that accompany "successful aging" in most of the dogs in this study were reasonably mild. The modal frequency of problem behaviors and abnormal ingestive or locomotory items was low, and the effect on memory and learning was minimal. A slightly different view emerges, however, when one looks at the percentage of the cohort that had deteriorated significantly over the previous 6 months. More than half of the items were reported to have shown a greater than 10% incidence of deterioration. In particular, activity and play levels, response to commands, and fears and phobias showed considerable deterioration. Although the overall behavioral responses shown by most aged dogs can be considered normative, age-related changes in response frequency and

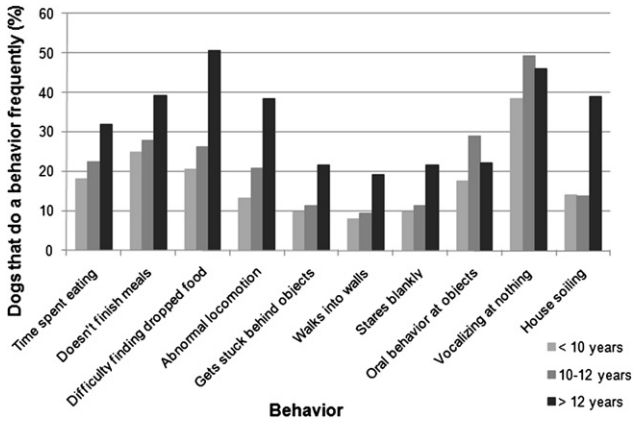

Figure 1 Behavioral items for which the reported incidence of dogs (n = 826) that frequently perform a behavior increased significantly ($P < 0.05$) across 3 age groups: <10, 10-12, and >12 years.

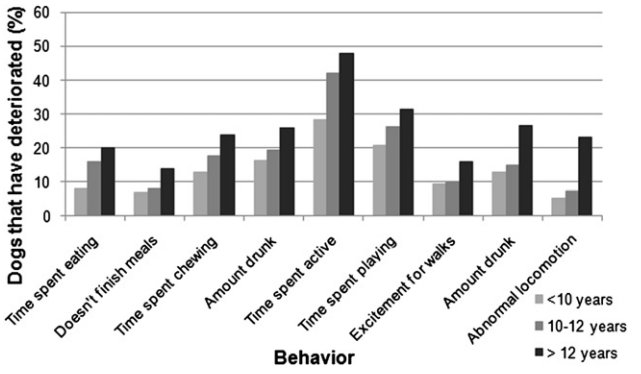

Figure 3 Ingestive, arousal, and locomotory items for which the reported incidence of dogs (n = 826) that deteriorated over a 6-month period significantly ($P < 0.05$) increased with age group: <10, 10-12, and >12 years.

severity occurred in a substantial portion of the population. For this reason, it may be more relevant to focus clinical attention on the average item frequency or deterioration across the different age groups.

When segregated into the 3 age groups, more than half of the behavioral items surveyed showed significant age-related changes. These items came from each behavioral subsection. Additionally, approximately two-thirds of responses showed a significant age-related deterioration in the severity of an item within a 6-month period. The measurement of deterioration within a 6-month period is particularly valid because it reflects change within an individual dog. This minimizes the potential effect of between-subject variation, such as breed.

Changes in ingestive behavior suggest that as dogs age, enthusiasm for eating and chewing declines. This is accompanied by a significant increase in the number of dogs drinking more water than 6 months previously. Rather than being a result of cognitive changes, it is likely that these changes occur as a result of contemporaneous age-related disorders, such as dental and periodontal disease, that reduce voluntary food intake (Holmstrom et al., 2005) and renal disease that reduces water conservation (Rubin, 1997). Regardless of the primary cause, it should be acknowledged that changes in ingestive behaviors do occur with age, and that these could adversely affect a dog's quality of life or other behavioral responses that rely on motivation for food, such as training responses.

Musculoskeletal degeneration with age is a common and well known phenomenon in dogs (Hoskins and Kerwin, 1997). Therefore, it is not surprising that age would increase the frequency and intensity of reported arousal and locomotory decline. This also helps to explain why the current data show a linear increase in percentage of dogs that have shown deterioration in their time spent being active per day and in their time spent in playing, that is, a decrease in both activities. Likewise, an increased proportion of dogs

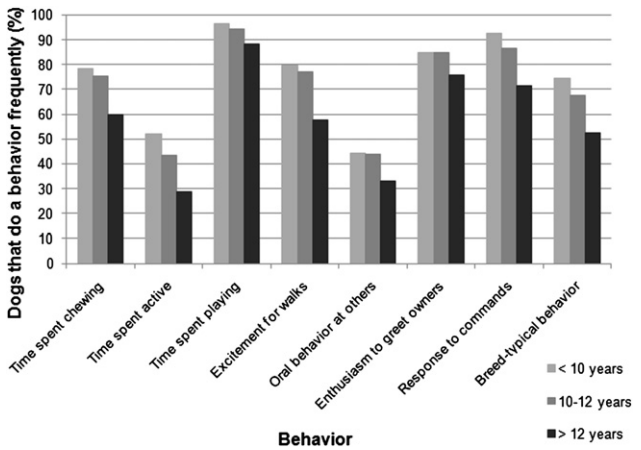

Figure 2 Behavioral items for which the reported incidence of dogs (n = 826) that frequently perform a behavior decreased significantly ($P < 0.05$) across 3 age groups: <10, 10-12, and >12 years.

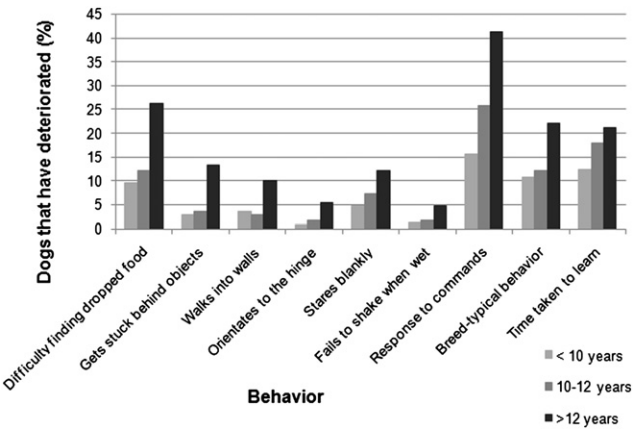

Figure 4 Learning and memory items for which the reported incidence of dogs (n = 826) that deteriorated over a 6-month period significantly ($P < 0.05$) increased with age group: <10, 10-12, and >12 years.

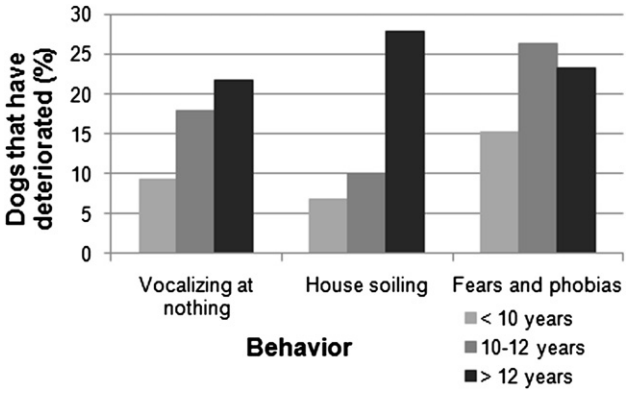

Figure 5 Problem behavior items for which the reported incidence of dogs (n = 826) that deteriorated over a 6-month period significantly ($P < 0.05$) increased with age group: <10, 10-12, and >12 years.

that are less interested in walks is most probably a reflection of physical degeneration, but could also indicate apathy or a reduction in a dog's awareness of its surroundings. An increase in the percentage of dogs waking at night more often and displaying more abnormal locomotory responses, such as circling, pacing, and wandering, than 6 months previously may have physical origins, but importantly these often reflect changes in cognitive processing (Landsberg et al., 2003). Such trends in behavior are of critical importance because they are likely to compromise the dog–owner bond, and may contribute to the kind of negative feelings owners can have toward older dogs (Baranyiova et al., 2004).

The decreased frequency of oral activity (licking or nibbling) toward people or other pets seen with increasing age group is of interest. In many mammals, mutual grooming has been shown to be an important part of social communication (Sato et al., 1993; Sigurjonsdottir et al., 2003; Gomes et al., 2009), and physical human–dog interactions are known to have a positive influence on physiological measures of stress in both parties (Odendaal and Meintjes, 2003; McGreevy et al., 2005; Coppola et al., 2006). The decrease in the types of oral responses reported in this study could indicate a reduced interest in maintaining social bonds or a general apathy toward physical stimuli. If either of these were the case, it would be expected that there would also be a change in other measures of social bonding, such as time spent in close proximity to human beings and an inclination to be petted or touched. Although both of these specific measures did show an increase in frequency and deterioration rates with age group, neither approached significance.

As has already been discussed, it is well known that age has an adverse effect on learning and memory in dogs. It is therefore unsurprising that several items reflective of learning and memory showed changes in both frequency and deterioration measures with increasing age group. That said, in the absence of a physical examination, it may be difficult to exclude physical degeneration as the cause of apparent changes in cognition. As an example, staring blankly at the walls or floor, reduced obedience, and difficulty in finding dropped food, all showed an increased percentage of dogs that had deteriorated with age group. These items could be a result of physical degradation of the visual, audio, or olfactory organs, but could equally reflect alterations in the cognitive processing of sensory information. Of particular interest in the current data is the increased deterioration of breed-typical behaviors such as herding, pointing, and retrieving. Although not applicable to all dogs in the cohort, overall, there was a 2-fold increase in the percentage of dogs that performed breed-typical behavior less often than 6 months previously, comparing dogs aged >12 years with those aged <10 years. Again, further investigation is required to determine the relative roles of physical or cognitive decline in this finding.

The frequency and deterioration of house soiling showed an exponential increase with advancing age group. This is comparable with several studies investigating the more advanced stages of cognitive aging (Bain et al., 2001; Neilson et al., 2001), and with the primary reasons for behavioral referral in aged pets (Landsberg et al., 2003). Although some medical conditions can cause loss of bladder or bowel control, reduced spatial awareness or loss of toilet training should also be considered as a possible cause of house soiling. Given that there is a significant age group effect, and that the level of deterioration over a 6-month period is also significant, it seems unlikely that the pattern obtained in this study is the legacy of persistent house soiling from puppyhood.

Several shortcomings of the current study must be acknowledged. Survey data, particularly those collected through the Internet, are subject to criticisms based on the inability to screen respondents for their suitability or to standardize the level of dog awareness among owners (Miklosi, 2007). This study attempted to address this possible selection bias by targeting respondents with what we anticipated to be a high level of interest in their pets, either readers of dog enthusiast magazines and Web sites or staff and students of veterinary colleges.

To avoid the effects of anthropomorphism, another shortcoming that is characteristic of owner-based surveys, this study focused on frequency-based questions to quantify items and avoid qualitative assessments of behavior. Any mention of problem behavior or cognitive dysfunction was absent from the recruitment phase to avoid a selection bias toward owners of problem dogs. It must be acknowledged that some bias may have occurred because of some items being more offensive or noticeable to owners as compared with other, more benign, items. The possible influence of breed differences in the aging process is an extensive investigation on its own and therefore was not addressed in this article. A previous study (Salvin et al., 2010) found no significant differences in the estimated prevalence of cognitive dysfunction between dog breeds of different size or

longevity groups, suggesting that cognitive aging may not be breed sensitive. Building on the data presented in this article, the authors have addressed this in a separate publication (Salvin et al., in press).

Although the issues with survey-based methodology cannot be entirely controlled for, the use of a survey has allowed us to collect large amounts of data across several breeds and geographical ranges. These data should not be viewed as an authoritative treatise on the behavior of "successful aging" dogs, but rather as a basis for future research in this area and as a guide to the possible effects of age on dogs outside of the laboratory. In particular, data relating to the deterioration of behavior as compared with 6 months previously should be considered most valuable because these avoid some of the problems related to frequency data alone. An important next step will be to conduct a longitudinal study identifying the relative sequence and rate of behavioral deterioration in "successfully aging" dogs.

Conclusion

We isolated a subset of behaviors that show significant age-dependent change in frequency (n = 18) or level of deterioration (n = 21). This knowledge will allow people to better identify which behavioral changes are a result of "successful aging" and which may be indicative of a clinical pathology in dogs. The behavioral profile of "successfully aged" dogs will also allow owners to be more aware of the behaviors that their aging pet may develop. By improving the knowledge base, not only of owners but also of ethologists, veterinarians, and dog trainers, the expectations of all parties may better align with the realities of the aging process. Finally, dogs' welfare and quality of life will be improved by maintaining the dog–owner bond and facilitating research into the aging community dog.

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