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Title:
Owner reported sensory impairments affect behavioural signs associated with cognitive decline in dogs

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Abstract
To describe the extent of age-related cognitive decline in dogs, information regarding the baseline occurrence of associated behaviours in the general population is necessary. With a seven-item, data driven Age-Related Changes scale, we evaluated the relationship between sensory functions, training, sex, and the occurrence of behavioural signs associated with cognitive decline across the whole adult lifespan. The twofold difference in lifespan between small and large dogs presents challenges for ageing studies, with no widely accepted method to control for body size as it relates to chronological age and longevity, when comparing behavioural signs of cognitive decline. To address this issue, we utilized relative age, calculated using the estimated expected lifespan of the individuals in our questionnaire study. Signs of cognitive decline were already detectable in 'Mature' dogs (at 50-75% of the expected lifespan). Visual, auditory and olfactory impairments all resulted in significantly higher scores on the Age-Related Changes scale. Participating in dog training activities was revealed to be protective against behavioural signs of cognitive decline in aged dogs as perceived by the owners. These results revealed possible beneficial effects of training on cognitive ageing and emphasize the importance of routinely screening the sensory capacities of ageing dogs.

Keywords (indexing terms), maximum 6 items

Sensory impairment, dog ageing, cognitive decline, dog training, CDS, CCD

Highlights

- We controlled for lifespan differences between small and large dogs via relative age

- Signs of cognitive decline already detectable in mature dogs, before geriatric age

- Sensory impairments were associated with more cognitive decline related behaviours

- Dog training was associated with delayed signs of cognitive decline in aged dogs

1. Introduction

Ageing, including decreasing adjustability (Rose et al., 2012), affects every dog above a certain age. Age-related changes in dogs have been described in various behaviour tests measuring different facets of cognition, such as attention (Wallis et al., 2014a), problem solving (González-Martínez et al., 2013) and reversal learning (Mongillo et al., 2013). The majority of these results show diminished performance of older dogs compared to young ones, even when the old population only contained normally ageing subjects, excluding dogs showing signs of cognitive dysfunction. However, differentiating between dogs showing signs of normal aging or early signs of cognitive dysfunction based on direct behavioural measures has proven to be a challenging task (Rosado et al., 2012).

Cognitive dysfunction syndrome is described as a progressive neurodegenerative disorder, in which the diagnosis of pathological brain ageing is achieved by evaluating the associated behavioural signs and excluding other medical conditions (Landsberg et al., 2011). Several publications have described cognitive dysfunction in aged dogs and provided specific questionnaires for clinicians and owners (Azkona et al., 2009; Landsberg et al., 2011; Madari et al., 2015; Salvin et al., 2012), in order to assess the prevalence, progression and risk factors of cognitive dysfunction in the ageing dog population. The different scales being currently used in parallel in the literature (e.g. Madari et al., 2015; Salvin et al., 2011) show huge variation in their estimation of the proportion of affected dogs (ranging from 14 % to 68 %, depending on the scale and the senior dog population), with age being the greatest known risk factor (Azkona et al., 2009; Neilson et al., 2001). Whether changes regarding the prevalence of these behaviours are detectable before 8 years of age has not been investigated. Findings regarding other risk factors such as body size, sex, and neuter status have been contradictory (Azkona et al., 2009; Fast et al., 2013; Hart, 2001).

Most scales utilize separate subscales (domains), such as spatial orientation or house soiling as a basis of their scoring system, but the lack of item stability within categories across questionnaires is problematic. For instance, the item “Decreased recognition of/Does not recognise familiar people” has been classified as a sign of impairment in three different domains depending on the study: “Disorientation” (Osella et al., 2007), “Social interactions” (Azkona et al., 2009), and “Learning and memory: work, tasks, commands” (Golini et al., 2009). To date no report of the internal consistency of these domain specific scales has been published. In case of the Canine Dementia Scale (CADES), the four domain specific scores (spatial orientation, social interactions, sleep–wake cycles and house soiling) were highly correlating with the sum score (Madari et al., 2015). The missing information regarding the internal consistency of the scales is problematic, as behavioural and questionnaire studies often use the domain specific subscales as a basis for categorization of the various stages of cognitive dysfunction syndrome. For example, a domain (e.g. social interaction) is considered impaired if the dog shows more than one domain specific behavioural sign and the dog is categorized to suffer from severe CDS if at least three domains are impaired (Azkona et al., 2009; Bain et al., 2001; Rosado et al., 2012).

Another problematic issue with previous reports based on owners’ assessments is that they did not specifically address the influence of sensory decline on the reported behaviours in the questionnaires. This can be a confounding factor in these type of studies, as the prevalence of sensory impairments seems to increase with age. Urfer et al. (2011) reported that in dogs older than 5 years the incidence of cataract was 8.7%, while among old dogs (7-10 years) 14.1% of the population was affected, and this rate is probably even higher in senior dogs. A study by Ter Haar et al. (2010) showed auditory impairment in middle aged or older dogs compared to young ones.

Nevertheless, little effort has been taken to account for dogs displaying perceptual impairments in case of online questionnaire studies implying to evaluate cognitive dysfunction. For example, in Salvin et al. (2010), the data of the 957 dogs used to develop (Salvin et al., 2011, 2010) and test (Salvin et al., 2011) the CCDR scale, included 290 dogs reported to suffer from deafness and 226 dogs from blindness. The authors concluded that dogs categorized as suffering from CCD have an almost threefold increase (Odds ratio=2.93 after correction for age) in the likelihood of being also blind (Salvin et al., 2010).

The considerably shorter lifespan of larger dogs (Galis et al., 2006) has been rarely taken into account. Demographic data suggests that large dogs do not simply suffer from a higher mortality in general (small breeds are expected to live about 10–14 years, some large breeds in contrast only live about 6–8 years), partly because they age faster (Kraus et al., 2013). This results in a decrease in the proportion of large and giant dogs in the oldest age groups in these studies, another possible confounding factor (Szabó et al., 2016). As the size of the dog is connected to differences in both the dog and owner characteristics (e.g. smaller dogs were reported to be more anxious in general and owners' of smaller dogs engaged less in training activities and play with their dogs) (Arhant et al., 2010), not controlling for this effect may influence the behaviours associated with cognitive decline.

Our goal in the current study is (1) to evaluate the internal consistency of the most widely used domain specific scales (Golini et al., 2009) on a large sample of dogs, and (2) to investigate the impact of various factors (sensory deficits, training) on the occurrence of behavioural signs associated with cognitive decline, taking into account the differences in expected lifespan of small and large dogs. We aimed to control for lifespan differences to ensure the presence of large dogs in our oldest age groups, with a formula provided by Greer et al. (2007). This formula estimates the expected lifespan in years based on the height and weight of the subjects (see Methods for further details). We decided to calculate the expected lifespan for purebred dogs instead of using breed specific lifespan data available in the literature, because the reported values were suggested to underestimate population lifespan due to right censored data (Urfer, 2008) and we wanted to include mixed breed dogs, too. We divided the age of the subject with its expected lifespan to control for the fact that e.g. at 7 years a large dog is nearly at the end of its expected lifespan (100%), while a small dog of the same age is only at half of its expected lifespan (50%). This step was necessary to create a more balanced sample across the age groups of different sized dogs. Because large dogs die younger, smaller dogs are overrepresented among old dogs. However, we should note, that using the relative age might decrease the prevalence of cognitive decline in the geriatric cohort, as currently there is no evidence about cognitive decline in giant dogs (i.e. it is possible that they generally die before the onset of cognitive decline). We decided to collect data across the entire adult lifespan of dogs, as we were interested in the baseline prevalence of the associated behaviours in a young population, and because laboratory beagle studies reported changes in cognitive performance as early as 6-9 years (Studzinski et al., 2006).

2. Methods

2.1. Subjects

This study used a cross-sectional design, with a total of 1343 online questionnaires from dog owners who volunteered to fill in the survey about dogs older than one year. For the descriptive data of the sample, see Table 1.

Table 1 Descriptive statistics of the sample. Size data was calculated from AKC breed standards in the case of purebred dogs and from individual data in mixed breed dogs.

Age	8.45 ± 4.5 years (mean ± SD) Range: 1-25 years
Age group	1-4 years: 342 (25.5%) 5-7 years: 265 (19.7%) 8-10 years: 264 (19.7%)) 11-13 years: 265 (19.7%) 14+ years: 206 (15.4%)
Relative age	0.69 ± 0.36 (mean ± SD) range: 0.07-2.77
Relative age group (percentage of lifespan)	Junior (≤25 %): 157 (13.0 %) Adult (25 % - ≤50 %): 268 (22.2%) Mature (50 % - ≤75 %): 252 (20.9%) Senior (75 % - ≤100 %): 245 (20.3%) Geriatric (100 %≤): 284 (23.5%) 137 missing data
Breed	Purebreds: 927(1-53 individuals from 122 breeds) Mixed breeds: 416
Sex	Intact male: 452 (33.7%) Intact female: 284 (21.1%) Neutered male: 192 (14.3%) Neutered female: 415 (30.9%)
Weight	Small (below 12 kg): 429 (34.8 %) Medium (between 12 and 30 kg): 478 (38.8 %) Large (over 30 kg): 324 (26.3 %) Missing data: 112
Height	Small (below 35 cm): 386 (32 %) Medium (between 35 and 43 cm): 218 (18.1 %) Large 602 (over 43 cm): (49.9 %) Missing data: 137
Hearing impairment	No: 800 (60.0%) Probably no: 204 (15.3%) Probably yes: 143 (10.7%) Yes: 186 (14.0%) Missing data: 10
Visual impairment	No: 768 (57.8%) Probably no: 218 (16.4%) Probably yes: 161 (12.1%) Yes: 182 (13.7%) Missing data: 14
Olfactory impairment	No: 968 (72.8%) Probably no: 263 (19.8%) Probably yes: 84 (6.3%) Yes: 15 (1.1%) Missing data: 13
Did the dog receive any kind of training certification, or entered any kind of competition?	No: 746 (74.4%) Yes: 257 (25.6%) Missing data: 340
Where does the dog spend most of the time?	House/Flat: 724 (72.2%) Garden: 259 (25.8%) Kennel: 20 (2.0%) Missing data: 340

2.2. Calculating relative lifespan

To control for the shorter lifespan of larger dogs, we utilized relative age in our analysis (chronological age in years divided by the expected lifespan in years). Based on the equation provided by Greer et al. (2007), we calculated the individual's expected lifespan from weight and height data: lifespan/years/ = 13.620+(0.027638*height)-(0.118609*weight). Height was measured in cm and weight in kg (Greer et al., 2007). Regarding individual's weight and height data, in the case of purebred dogs, we relied on the American Kennel Club (AKC) breed standards (the mean values calculated from the limits of the breed standards). In the case of mixed breed dogs, due to the huge variance in their size, we decided to calculate lifespan from the individuals' height and weight data provided by the owners in the questionnaire, using the aforementioned equation. Mixed breed dogs without weight and height data were excluded from further analysis.

Based on the relative age of the dog, we decided to allocate dogs to age groups as previous research has shown that multiple behavioural traits display a quadratic relationship with age in dogs (Wallis et al., 2014b). We grouped the dogs into five age groups according to the American Veterinary Medical Association (AAHA) Canine Life Stage Guidelines (Bartges et al., 2012): junior (relative age up to 25 % of the expected lifespan), adult (relative age between 25-50%), mature (relative age between 50-75%), senior (relative age between 75-100%) and geriatric (individuals which have already outlived their expected lifespan). Based on the relative age calculation and grouping, an 8-year-old Bichon Bolognese would be categorized as mature, while a Great Dane of the same age would be categorized as senior. With this approximation, our aim was to compensate for the difference seen between large and small dogs in their expected lifespans and create categories that correspond better to the life stages than chronological age itself, therefore make comparisons and generalisations among dogs of different sizes possible.

2.3 Online survey

The online Hungarian survey contained questions about the dog's demographic parameters and about the dog's current behaviour based on a questionnaire by Golini et al., (2009), which contained 31 behaviour related questions (See Table 2). We decided to select the questionnaire that covered the widest range of domains and questions available, and which has been validated by independent behavioural or neural measures (neurologic evaluation by a veterinarian). Regarding sensory impairments, owners indicated on a four-level scale whether they were aware of a suspected sensory decline in the given domain (no, probably no, probably yes, yes). Owners were offered the option to select: 'I don't know/ I don't want to answer this question' to avoid forced answers. The latter answer resulted in exclusion from further analysis.

Table 2. List of the behaviour related items of the questionnaire. Two types of closed answers were utilized, when a "*" is indicated at the end of the question: Never, rarely, sometimes, often, very often; and a "#": 1(strongly disagree) 2 3 4 5 (strongly agree). Owners were offered the option to choose 'Do not know/I do not want to answer this question' for every question. Spearman' rho is presented to examine correlations between relative age and questionnaire item scores. The P values for Spearman's Rho were <0.001, unless indicated otherwise: NS p>0.05; ^ p>0.01.

Category/Item	Spearman's rho
A: Confusion, awareness, spatial orientation	
A1: Does your dog get lost in familiar locations? *	0.301
A2: Does dog goes to the wrong side of door (e.g., hinge side)? *	0.308
A3: Does your dog get stuck, cannot navigate around or over obstacles? *	0.249
A4: Is your dog barely reacting/unresponsive toward stimuli? *	0.426
B: Relationships, social behaviour	
B1: Is your dog recently showing decreased interest in petting/contact? #	0.223
B2: Is your dog recently showing decreased greeting behaviour when you arrive home? #	0.438
B3: Is your dog experiencing alterations/problems with social hierarchy? #	0.144
B4: Is your dog in need of constant contact, over dependent, clingy? #	0.201
C: Activity: increased/repetitive	
C1: Does your dog stare/fixate/snap at objects? *	0.183
C2: Does your dog pace/wander aimlessly? *	0.303
C3: Does your dog excessively lick you or household objects? *	-0.169
C4: Is your dog vocalizing a lot/excessively? *	-0.061^
C5: Has your dog's appetite increased recently? (eating too fast, would like to eat more) #	0.228
D: Activity: decreased/apathy	
D1: Is your dog showing decreased exploration/activity/apathy? *	0.464
D3: Is your dog showing decreased self-care? *	0.362
D4: Has your dog's appetite decreased recently? #	0.244
E: Anxiety: increased irritability	
E1: Is your dog restless/agitated? *	-0.084^
E2: Is your dog anxious when it cannot be with you? *	-0.05 NS
E3: Is your dog recently showing increased irritability? *	0.078
F: Sleep–wake cycles: reversed day/night schedule	
F1: Is your dog recently experiencing restless sleep/waking at nights? *	0.223
F2: Is your dog recently sleeping more than usual during daytime? *	0.587
G1: Learning and memory: housetraining	
G1.1: Does your dog eliminate indoors at random sites or in view of owners? *	0.255
G1.2: Does it happen that your dog does not or barely signals that it needs to go out? *	0.230
G1.3: Does your dog go outdoors, then returns indoors and eliminates? *	0.203
G1.4: Does your dog eliminate in its crate or sleeping area? *	0.260
G1.5: Is your dog suffering from incontinence? *	0.290
G2: Learning and memory: work, tasks, commands	
G2.1: Is your dog showing impaired working ability/performs worse than it used to? *	0.417
G2.2: Does your dog have difficulties with or is not able to recognise familiar people/pets? *	0.270
G2.3 Is your dog less responsive to known commands and tricks? *	0.323
G2.4: Is your dog having difficulties with/is unable to carry out tasks/commands in general? *	0.348
G2.5: Is your dog slow/unable to learn new tasks? *	0.360

2.4. Data analysis

Statistical analysis was carried out via SPSS version 22. The internal consistency within the domain scales was investigated by Cronbach's alpha. We used Spearman' rho for examining correlations between relative age and the 31 questionnaire item scores. After evaluating the internal consistencies of the domains, we decided to use a short data driven general scale instead of these domain specific scales. To retain questions from as many domains as possible, we selected within each domain the item that correlated positively with relative age with the highest rho, as age is the greatest known risk factor for cognitive decline. We calculated the mean score of these items and labelled the scale as Age-Related Changes (ARC). A univariate General Linear Model (GLM) with a backward elimination process was used for testing the effect of the explanatory variables on the Age-Related Changes scale. The main effects for all variables included: relative age group, sex & neuter status, height (small, medium, large), weight (small, medium, large), hearing impairment, visual impairment, olfactory impairment, training history (yes/no), keeping condition (house, garden, and kennel) and 2-way interactions with the relative age groups. Significant effects were tested with Student-Newman-Keuls (SNK) post hoc test to examine differences in group means.

3. Results

We investigated the internal consistency of the eight domains from Golini et al., (2009). Cronbach's alpha (CA) scores are reported in Table 3. According to the CA scores only 'Spatial orientation', 'Housetraining', and 'Learning and memory' domains had appropriate internal consistency based on our Hungarian population's responses (CA>0.7).

Table 3 Cronbach' alpha scores of the survey's (based on Golini et al., 2009) domain specific scales.
*: B4 item was reverse scored

Scale	N of items	CA
Spatial orientation A	4	0.828
Social behaviour B*	4	0.526
Increased activity C	5	0.545
Apathy D	3	0.668
Anxiety E	3	0.559
Sleep-wake cycles F	2	0.518
Housetraining G1	5	0.859
Learning and memory G2	5	0.877

In case of the "Anxiety" domain, only one item ("Is your dog recently showing increased irritability?") correlated positively with age (rho=0.078, Table 2), while a different item ('Is your dog restless/agitated?') had the highest absolute rho value (Spearman's rho = -0.084, p=0.004). Since the correlations in within this domain were much weaker compared to the other domains, we decided to exclude the "Anxiety" domain from the short scale. The final items that were selected for the overall ARC score are listed in Table 4. The CA for the final seven items was 0.849, and the ARC score ranged from 0 to 4 (mean ± SD = 0.836 ± 0.830).

Table 4 The items of the Age-Related Changes scale and their Spearman's rho correlation coefficient with relative age (all reported values are significant at P < 0.001)

Item	Spearman's rho
A4: Does it happen that your dog is barely reacting/unresponsive toward stimuli?	0.426
B2: Is your dog recently showing decreased greeting behaviour when you arrive home?	0.438
C2: Does it happen that your dog is pacing/wanders aimlessly?	0.303
D1: Does it happen that your dog is showing decreased exploration/activity/apathy?	0.464
F2: Is your dog recently sleeping more than usual during daytime?	0.587
G1.5: Is your dog suffering from incontinence?	0.290
G2.1: Does it happen that your dog is showing impaired working ability/performs worse than it used to?	0.417

According to the GLM, after the backward elimination process, the following explanatory variables had a significant effect on the Age-Related Changes scale: relative age group*training history ($F(4,785) = 3.41$, p 0.009), relative age group ($F(4,785) = 10.72$, $p < 0.001$), hearing impairment ($F(3,785) = 23.74$, $p < 0.001$), visual impairment ($F(3,785) = 10.79$, $p < 0.001$) and olfactory impairment ($F(3,785) = 7.00$, $p < 0.001$) (See Table 5 for effect sizes). Regarding visual and hearing impairment, all severity categories differed from each other in regard the Age-Related Changes scale scores (Figure 1A & 1B); dogs with intact sensory function scored lower on the Age-Related Changes scale, with a steady increase in score toward replies indicating more severe impairments (owners who were certain their dog is suffering from loss of sensory function). In the case of olfactory impairment, sensory intact individuals had lower Age-Related Changes scores than dogs suffering from sensory impairment and showed a gradual decline in cognition toward certain impairment, with no difference between the probably and certainly impaired groups (Figure 1C). The largest effect size (Partial Eta 0.083) was related to acoustic impairments, exceeding the effect size of relative age (0.052).

Figure 1. Mean and SE of scores of the Age-Related Changes scale by sensory impairment categories as reported by the owner. A, visual impairment B, hearing imnpairment C, olfactory impairment. Different letters mark significant differences (p<0.05) between the categories based on SNK post hoc test.

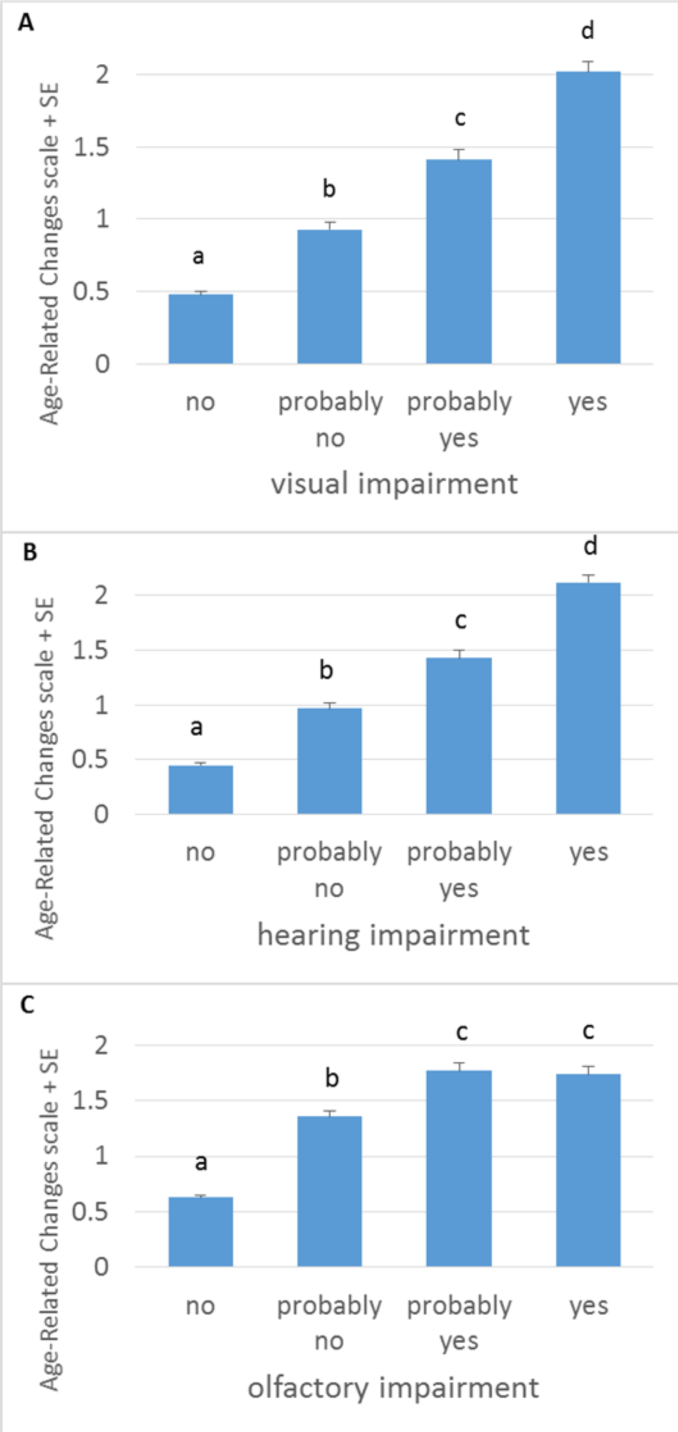

Table 5 Results of the Univariate General Linear Model analysis for the Age-Related Changes scale scores after the removal of the non-significant interactions and main effects from the model.

	df	F	Sig	Partial Eta Squared
Relative age	4	10.72	<0.001	0.052
Acoustic impairment	3	23.74	<0.001	0.083
Visual impairment	3	10.79	<0.001	0.040
Olfactory impairment	3	7.00	<0.001	0.026
Training	1	1.96	0.162	0.002
Relative age*training	4	3.41	0.009	0.017
Error	785			

Mature dogs (50-75% of expected lifespan) were already reported by their owners to experience significantly more signs of cognitive decline than young dogs (≤25% of expected lifespan), and older relative age groups showed progressively more signs (Figure 2 and Table 5). Relative age group showed an interaction with training history. In 'Senior' and 'Geriatric' age groups (over 75 % of expected lifespan), lower Age-Related Changes scores were reported in the case of trained dogs (Figure 3), while no such difference was present among younger dogs of differing training status. Sex, neuter status and the size of the dog had no significant effect on the Age-Related Changes score.

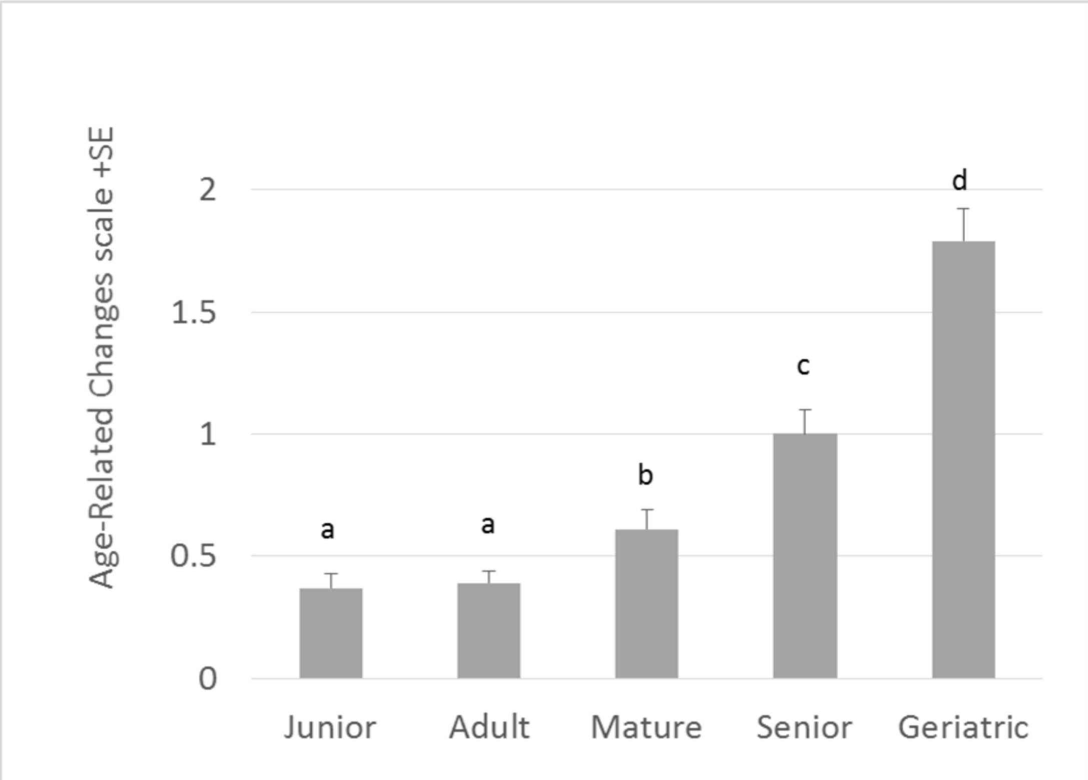

Figure 2. Mean and SE of scores of the Age-Related Changes scale for the relative age groups. Different letters mark significant group differences (p<0.05) between the groups based on SNK post hoc test.

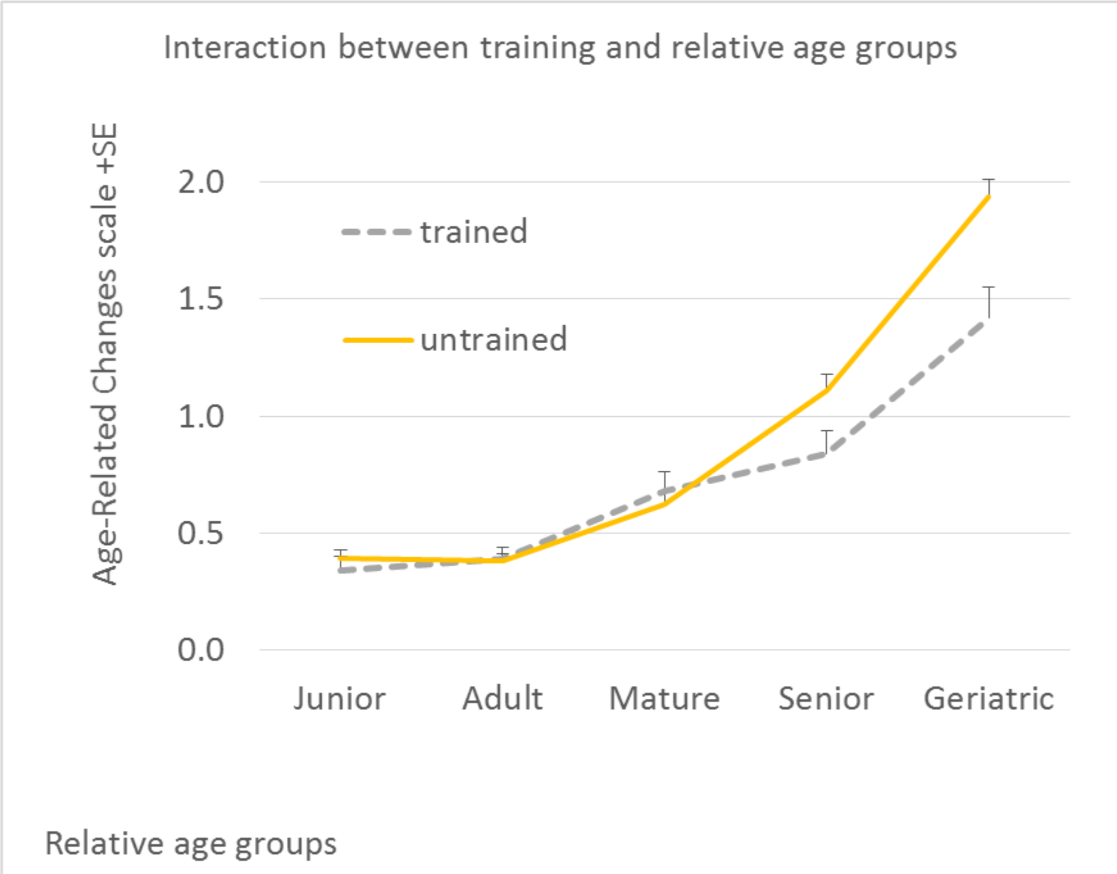

Figure 3. Mean and SE of scores of the Age-Related Changes scale for the relative age group-training interaction.

4. Discussion

In this study we created a short, data driven scale based on the items' positive correlation with relative age. The resulting seven items of the Age-Related Changes scale showed that beside relative age, impairments in every sensory domain and training history were associated with behavioural problems reflecting cognitive decline in a convenience sample of family dogs. As we conducted an online survey (similarly to other studies, e.g. Salvin et al., 2010), we had no possibility to gather accurate medical data from our subjects. We cannot exclude that the reported behaviours are related to medical conditions other than cognitive dysfunction syndrome, therefore we cannot comment on the prevalence of this condition. Our goal was to gather information about the relationship between the putative behavioural signs of cognitive decline and relative age, sensory impairments and certain demographic factors (sex, breed, training) across the whole adult lifespan.

Before the development of our scale, we tested the internal consistency of the domains of the Golini et al. (2009) questionnaire, which is used for grading dogs according to the severity of cognitive dysfunction. We found that five out of the eight scales used have not shown reliable internal consistency on a Hungarian sample. This warrants caution when the criteria of grouping are based on the number of signs shown within a domain. The exclusion of the anxiety domain from our Age-Related Changes scale, due to a lack of strong correlation with relative age supports the findings of Madari et al. (2015), who also found that anxiety shows a low level of sensitivity and predictive value for cognitive dysfunction.

The reported behavioural signs of cognitive decline started to become more prevalent already in the mature group (50-≤75% of the expected lifespan, which corresponds roughly to a 4-6 years old Great Dane or 7-10 years old beagle), and was followed by an accelerating decline in the older age groups. Our results resemble findings in normally ageing laboratory beagles, as Studzinski et al. (2006) detected signs of cognitive decline at the age of 6-8 years using a complex learning task After controlling for differences in expected lifespan, Age-Related Changes scores were independent of the size of the dog, i.e. small dogs did not receive higher scores. The lack of an age group-size interaction suggests that cognitive decline may start earlier in larger dogs, but this issue requires further investigations on a larger sample.

As expected, we found sensory problems as reported by the owners to be associated with a higher number of problematic behaviours regardless of relative age groups. Wayne and Johnsrude (2015) proposed a direct link between sensory systems and cognition, but the nature of this relationship (whether one precedes the other and whether there is a common underlying cause responsible for both sensory and cognitive decline) requires further experimental studies. An alternative explanation for this relationship could be that the behavioural signs of sensory impairment overlap with the signs of cognitive decline (e.g. a blind dog cannot navigate around objects). However, this is unlikely, given the fact that every sensory domain showed this effect, even olfaction, and that slight uncertainty regarding the complete health of the sensory organs was already associated with higher scores on the Age-Related Changes scale. Another possibility is that the dogs reported to suffer from sensory impairments were simply unreactive toward stimuli. While we cannot exclude this without a veterinary exam, the fact that owners who were simply uncertain whether their dogs suffer from sensory impairment already reported more signs of cognitive decline, supports that even the narrowing of perceptual skills, and not only the total loss of sensory function can affect the welfare and behaviour of geriatric dogs. This highlights the need for screening and detection of the early stages of sensory impairment in veterinary praxis with adequate and feasible tests.

Training history, i.e. participating in formal dog training or competition in dog sports seems to delay cognitive decline later in life. Among the 'Senior' and 'Geriatric' groups (above 75% of lifespan), trained dogs received significantly lower Age-Related Changes scores. Education level seems to have a similar positive effect on the retention of cognitive capacities in humans (Caamaño-Isorna et al., 2006), and training history was also reported to be a protective factor in a sustained attention task among aged dogs (Chapagain et al., 2017). Since formal dog training has been reported to increase problem solving ability in young dogs (Marshall-Pescini et al., 2008), an alternative explanation could be that training, independently from age is associated with better performance. However, this is unlikely to be the case here, because in our sample there was no difference between trained and untrained young dogs, the difference only emerged with advancing age. Whether this is due to a cognitive reserve (Whalley et al., 2004), i.e. trained dogs have better cognitive capacities, therefore signs of cognitive decline become noticeable later in life, or if engagement in training helps maintaining cognition and modifies the ageing trajectory, cannot be answered by the current study. As we only collected very basic information on training history ('Did the dog receive any kind of training certification, or entered any kind of competition?'), we do not have data regarding the number, type or intensity of dog training activities, and whether the activity is currently ongoing or the dog has been retired. To investigate the role of other possible demographic reasons in this effect (e.g. owners who engaged in training activities with their dogs may also provide better nutritional and/or veterinary care for their older dog or lead a more active lifestyle), further, more detailed studies regarding dog training and age related cognitive decline are required. Additionally, whether this positive effect is observable when training/enrichment is started in old age (e.g. Milgram et al. (2005) but see Davis et al. (2017)), or it is rather related to cognitive reserve acquired at a young age as suggested in humans (Lenehan et al., 2015), requires further, more detailed studies. (Kyathanahally et al., 2015)

5. Conclusion

Putative signs of cognitive decline were already detectable in mature dogs (at 50-75% of the expected lifespan) via a short data driven scale addressing everyday situations for family dogs, which suggests that the processes resulting in cognitive dysfunction syndrome in later years start to operate before the onset of old age. This information needs to be considered when deciding on the most effective timepoint to intervene with possible therapies. Dogs suspected by their owners to suffer from sensory impairment scored higher on the Age-Related Changes scale, whereas participation in formal dog training activities was associated with delayed cognitive decline in old age. We successfully applied relative age to account for lifespan differences between small and large dogs, relying on expected lifespan calculated from the weight and size of the dogs. Based on our results, it is crucial to collect information about the sensory functions of aged dogs when evaluating cognitive decline with online questionnaires or behavioural tests. Intact sensory functions and dog training seem to be protective factors that can help to maintain the cognitive capacities of aged dogs.

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