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ORIGINAL PAPER

Phenotyping of Aggressive Behavior in Golden Retriever Dogs with a Questionnaire

L. van den Berg · M. B. H. Schilder · H. de Vries · P. A. J. Leegwater · B. A. van Oost

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Abstract Reliable and valid phenotyping is crucial for our study of genetic factors underlying aggression in Golden Retriever dogs. A mail questionnaire based on the Canine Behavioral Assessment and Research Questionnaire (CBARQ; *Hsu and Serpell, 2003, JAVMA 223(9):1293–1300*) was used to assess behavioral phenotypes. Owners of 228 Golden Retrievers completed the questionnaire. These dogs had been referred to our clinic for aggression problems several years earlier or they were related to aggressive dogs. In this paper, three sets of results are presented, which indicate that behavior scores from the CBARQ can be applied to genetic studies. First, factor analysis demonstrated that CBARQ items can be grouped into 10 behavioral traits, including three types of aggression: stranger-directed aggression, owner-directed aggression, and dog-directed aggression. The results were remarkably similar to those reported by Hsu and Serpell. The aggression scores showed considerable variation in our dog families, which is a prerequisite for genetic studies. Second, retrospective questions enabled us to study changes in the aggressive behavior of the dogs in the course of time. After an average time interval of 4.3 years, over 50% of the dogs had become less aggressive. Third, we analyzed data obtained with an aggression test of 83 dogs. Two out of the three CBARQ aggression factors were also found in the aggression test data.

Keywords Dog · Aggression · Phenotyping · Questionnaire · Aggression test

L. van den Berg (✉) · P. A. J. Leegwater
Department of Clinical Sciences of Companion Animals, Faculty of Veterinary Medicine, Utrecht University, Yalelaan 8, 3584 CMUtrecht, The Netherlands
e-mail: Linda.v.d.Berg@gmail.com

M. B. H. Schilder
Animals, Science and Society, Faculty of Veterinary Medicine, Utrecht University, Utrecht, The Netherlands

H. de Vries
Department of Behavioral Biology, Faculty of Biology, Utrecht University, Utrecht, The Netherlands

B. A. van Oost
American University of the Caribbean, #1 University Drive at Jordan Road, Cupecoy, St. Maarten, N.A., The Netherlands

Introduction

Dogs have been living in close proximity to humans since the last Ice Age (Clutton-Brock 1995). Like their progenitor the grey wolf, dogs respond with aggressive behavior to certain stimuli. This is natural behavior in the majority of cases (Borchelt and Voith 1996; Mugford 1984; Reisner 1997). However, canine aggression can develop into a dangerous problem (Winkler 1977; Wright 1985). There is individual variation in the tendency of dogs to display aggressive behavior. This variation is the result of a complex system of interacting genes and environmental influences, which is poorly understood. We study the genetics of aggression in families of Golden Retriever dogs (van den Berg et al. 2003a; 2003b; 2004; and 2005). Golden Retrievers are reputably friendly pets. However, there are reports of very aggressive Golden Retrievers (Edwards 1991; Galac and Knol 1997; Heath 1991; Knol and Schilder, 1999). This aggressive behavior seems to occur more often in certain family clusters than in others. It was

thus suggested that genetic factors play an important role (Knol et al. 1997).

Purebred dogs provide a promising tool for studies of the genetic basis of behavioral traits. A dog can only be registered as a member of a breed if both its parents are registered members of the same breed. As a result, dog breeds are genetic isolates (Parker et al. 2004). The low genetic heterogeneity within dog breeds implies that only a limited number of the genes that influence a certain behavioral trait will be functionally polymorphic within a breed. This greatly facilitates the chances of finding such genes. The uniformity within breeds is contrasted by the extraordinary variation in morphology and behavior between breeds. This combination of intrabreed homogeneity and interbreed diversity provides unparalleled opportunities for elucidating the genetics of behavior. Dog behavior could be a valid model for human behavior because human and canine social systems are similar (Overall 2000). For example, both dogs and humans show within group competition as well as cooperation. Dogs may represent a more valid model for humans than rodents because behaviors that are normal in rodents (e.g. hiding) would be considered pathological in humans and dogs. In addition, some dogs suffer from conditions that may be homologous to human mental disorders, e.g. generalized anxiety disorder, attachment disorders, social phobia, Alzheimer's disease, aggressive impulse control disorders, and obsessive-compulsive disorder (Overall 2000). An example of the latter condition in dogs is compulsive tail chasing, which has been shown to have a heritable component in Bull Terrier dogs (Moon-Fanelli 2002; Moon-Fanelli and Dodman 1998). With the completion of the dog genome project, the tools necessary for gene mapping studies in dogs have become readily available (Lindblad-Toh et al. 2005). The key to success of such studies is a reliable and valid method for phenotyping.

We previously used aggression tests for phenotyping (van den Berg et al. 2003a). Although such tests are more objective than owner-derived information, their disadvantage is that it is difficult to evoke problem behavior in a clinical setting. Indeed, we found that many Golden Retrievers that were aggressive according to their owner showed little or no aggression in the test (van den Berg et al. 2003a). In human behavioral genetics, questionnaires are regularly used as an alternative for behavioral tests (e.g. Bartels et al. 2003). Several authors have suggested that it is possible to obtain reliable information about dog behavior using questionnaires for dog owners (Gosling et al., 2003; Hsu and Serpell 2003; Serpell and Hsu 2001) A reliable, validated questionnaire to assess canine behavioral traits was presented by Hsu and Serpell in 2003. Their questionnaire, now named the Canine Behavioral Assessment and Research Questionnaire (CBARQ), contains 76 items regarding aggression, fear and anxiety, trainability, excitability, separation-related behavior, attachment, attention seeking, and chasing. By means of factor analysis, Hsu and Serpell demonstrated that the CBARQ items could be grouped into several behavioral traits, including at least three types of aggression: stranger-directed aggression, owner-directed aggression, and dog-directed aggression.

Hsu and Serpell (2003) evaluated the reliability of the CBARQ in a group of dogs of various breeds by calculating Cronbach's α, a measure of internal consistency. The reliability was acceptable for all aggression-related factors. Svartberg (2005) studied the internal consistency reliability of CBARQ scores in a population of Swedish dogs of various breeds. He found Cronbach's alpha values roughly in line, though somewhat lower, with the values obtained by Hsu and Serpell. Other aspects of reliability, such as test–retest and inter-rater reliability, were not reported. The factor structure of Hsu and Serpell (2003) seems to be stable across different populations of dogs since two other studies found similar factors (Goodloe and Borchelt 1998; Serpell and Hsu 2001). In an earlier study, Serpell and Hsu (2001) used a 40-item questionnaire for evaluating guide dog behavior. Several items in this questionnaire were similar to CBARQ items. They performed factor analyses in three breed groups (Labrador Retriever, German Shepherd dog, and Golden Retriever) and found factors similar to those in the 2003 study. This suggests that the factor structure is also stable within dog breeds. Hsu and Serpell (2003) studied the validity of seven CBARQ scores by comparing them with clinical diagnoses from behavioral practitioners. These diagnoses included ''aggressive toward owners'', ''aggressive toward strangers'', and ''aggressive or fearful toward unfamiliar dogs''. Dogs assigned to particular diagnostic categories had significantly higher scores for corresponding CBARQ traits than those assigned to unrelated diagnostic categories. Svartberg (2005) used the CBARQ to validate personality traits derived from a behavioral test, the Swedish Dog Mentality Assessment. He demonstrated that the CBARQ factor ''nonsocial fear'' correlated negatively with the personality trait of curiosity/fearlessness. In addition, ''stranger-directed fear'' correlated negatively with the trait of sociability. There were no significant correlations between ''chasing'' and ''stranger-directed aggression'' and their corresponding trait scores (respectively chase-proneness and aggressiveness).

The results of these studies suggest that the CBARQ is a reliable and valid method for evaluating canine behavioral traits. However, no studies have been devoted to the variation of CBARQ scores within dog families. We made a Dutch translation of the CBARQ and sent it to owners of 238 Golden Retrievers that had earlier participated in our project. In this paper, three analyses will be presented. First, we evaluate the usefulness of the CBARQ as a method for phenotyping. Phenotypic scores derived from the CBARQ should meet at least three requirements in order to be useful for future gene mapping studies. First, they should be reliable, i.e. the results should be consistent. Second, they should lead to valid conclusions, i.e. they should be a good approximation of what they purport to measure (aggression in this case). Third, they should display variation within families of dogs. The second topic that will be addressed here is the design and analysis of a shortened version of the CBARQ tailored for retrospective data on deceased dogs and for investigating behavioral changes over time. We made this shortened version because there was a gap of on average 4.3 years between the time that dogs participated in our project for the first time and the time the CBARQ was to be filled out. The behavior of the dogs might have changed in the meantime and we expected a number of dogs to be euthanized because of aggressive behavior. Third, we will present results of a further analysis of the aggression test data. In a previous study, we analyzed the behavior of 83 Golden Retrievers in the aggression test (van den Berg et al., 2003a). Behavioral scores were then obtained by summing frequencies of aggressive behavioral elements that were displayed in the subtests. Here, we investigate whether the subtests can be grouped into classes corresponding to CBARQ aggression types. Behavioral scores were now obtained by summing frequencies of aggressive behavioral elements in a class of subtests. The scores were compared to shortened CBARQ scores.

Methods

Subjects

We sent questionnaires to owners of two groups of Golden Retrievers. Group 1 consisted of 126 Golden retrievers that participated in our project in the period between October 1997 and October 2003 (Fig. 1). The majority had been subjected to the aggression test (van den Berg et al. 2003a). In addition, we had assessed characteristics of their aggressive behavior through a personal interview with the owner at the time of testing. Group 1 contained dogs that were still alive as well as dogs that had died. Group 2 consisted of 110 dogs that joined the project between October 2003 and February 2005. These dogs were not subjected to the aggression test and there was no personal interview with the owner. Both groups contained dogs that were referred to our clinic because of their aggressive behavior (probands) and dogs that were recruited by us because they were related to an aggressive dog (relatives).

Owners of 228 Golden Retrievers (97%) returned a completed questionnaire and 172 of these dogs were purebred with a pedigree. One hundred and ten were probands and 118 were relatives. There were 135 males (63 castrated) and 93 females (49 castrated) in the group. The mean age of the dogs was 6.6 years (range 6 months-14 years) at the time the questionnaire was filled out. Characteristics of the subjects are listed by group in Table 1.

Design of the Questionnaire

We developed three types of behavioral questions that were all based on the Canine Behavioral Assessment and Research Questionnaire (CBARQ): CBARQ items and two different types of shortened CBARQ questions. These questions will be described in more detail below. Table 2 provides an overview of the question types that were included in questionnaires for the different groups of dogs. Apart from the three types of CBARQ-based questions, two additional types of questions were included in each questionnaire: questions about environmental factors (not discussed here) and questions regarding the age of the dog, its sex and reproductive status, and its weight. These questions were added at the end of the questionnaire.

The Canine Behavioral Assessment and Research Questionnaire

We translated the Canine Behavioral Assessment and Research Questionnaire (CBARQ) into Dutch (Hsu and Serpell 2003; see the Appendix). All items in the questionnaire were worded to address the typical responses of the dog to specific situations and they were grouped in categories for simplicity (e.g. training and obedience, aggression, fear and anxiety). Owners were asked to score the behavior of their dog with 5-point frequency scales (i.e., 0 = never, 1 = seldom, 2 = sometimes, 3 = usually, and 4 = always) or 5-point qualitative rating scales (i.e. 0 = no signs of the behavior, 1–3 = mild to moderate signs of the behavior,

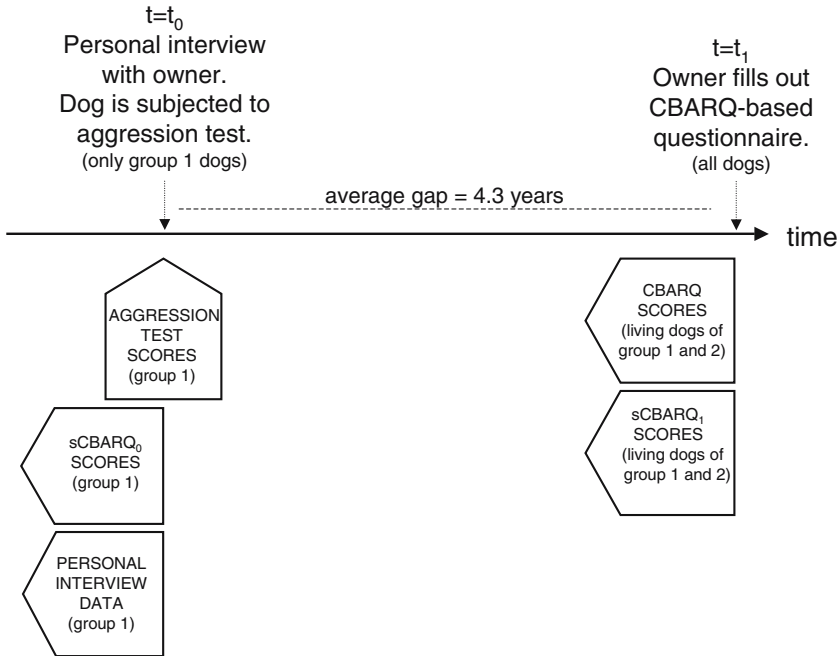

Fig. 1 In this figure, five behavioral measures that were employed in our study are placed in a time frame. Owners of group 1 dogs participated in our project at two separate time points. There was an average gap of 4.3 years between these time points. During the first participation ($t = t_0$), the owners were personally interviewed and the majority of the dogs were subjected to an aggression test. During the second participation ($t = t_1$), the owner filled out a questionnaire based on the canine behavioral assessment and research questionnaire (CBARQ). This questionnaire also contained questions referring to the time of first participation (i.e. $sCBARQ_0$ questions). Owners of group 2 dogs were only asked to fill out the questionnaire based on the CBARQ. Block arrows below the time line represent the five behavioral measures. Positions of the arrows relative to the time line reflect the time frame they address. For instance, $sCBARQ_0$ questions address the behavior of the dog in the months preceding the first participation

Table 1 Characteristics of the subjects by group

Group of subjects	Number of questionnaires returned	Sex		Mean Age (SD)	No. of probands	No. of pedigree dogs
		Males (castrated)	Females (castrated)			
Group 1						
living dogs	84	55 (30)	29 (21)	7.5 (2.4)	55	61
deceased dogs	36	26 (13)	10 (4)	–	28	19
Group 2						
living dogs	108	54 (20)	54 (24)	5.9 (3.2)	27	92
Total	228	135 (63)	93 (49)	6.6 (3.0)	110	172

Table 2 Distribution of three types of behavioral questions over three versions of the questionnaire and number of questionnaires returned

Version of questionnaire	Type of questions			Number of questionnaires returned
	$sCBARQ_0$questions[a]	$sCBARQ_1$questions[a]	CBARQ items[a]	
Group 1[b]				
living dogs	+	+	+	84
deceased dogs	+	–	–	36
Group 2[c]				
living dogs	–	+	+	108

[a] $sCBARQ_0$ questions address the behavior of the dog in the months prior to its first participation in the project, while $sCBARQ_1$questions and CBARQ items refer to the behavior in the recent past. Plus signs mark included types of questions

[b] Group 1 consists of dogs that had previously participated in our project

[c] Group 2 consists of dogs that were recently recruited

and 4 = severe signs of the behavior). For these rating scales, a brief explanation was included describing the sorts of behavioral signs involved in the behavior (e.g., ''Typical signs of moderate aggression in dogs include barking, growling, and baring teeth. More serious aggression generally involves snapping, lunging, biting, or attempting to bite.''). The CBARQ is a modified version of the PennBARQ that was described in 2003. It contains several additional questions (marked in the Appendix) (J.A. Serpell, personal communication). We asked the owners to fill out the CBARQ only if their dog was still alive.

Factor Analysis and Reliability of the Factors

Principal factor analysis was performed on 71 CBARQ items with response rates of at least 92%. A total number of 184 dogs was included in the analysis; eight dogs with more than four missing values were excluded. Missing values were replaced with the mean. We used the scree test to determine the number of factors to be extracted. Subsequently, the varimax method was used to rotate the factor solution. A second factor analysis with the same procedure was performed on the items that were included in the most relevant factors of the first factor solution.

Cronbach's alpha was calculated in order to study the internal consistency reliability of the factors. Items were assigned to the factor on which they had the highest loading. Dogs with missing values in a factor were excluded from the calculation for that particular factor. Factors with a Cronbach's alpha value of 0.70 or higher were considered to be reliable.

Calculation of Behavioral Scores from the CBARQ

We calculated behavioral scores as the mean of the CBARQ items that were grouped in a factor (e.g. stranger-directed aggression score = score for item 10 + 11 + 12 + 15 + 16 + 18 + 20 + 21 + 22 + 28/10). We will refer to these behavioral scores as ''CBARQ scores'' in the remaining of this paper. An additional score was calculated as the mean of items 32–35. These items were added to the PennBARQ by Hsu and Serpell to represent familiar dog aggression (FDA; J.A. Serpell, personal communication). They were excluded from the factor analysis because of the low response rate. Items 43, 50, and 51 were excluded from calculation of CBARQ scores and item 64 was included in the ''attachment, attention seeking, and excitability'' score instead of the chasing score in order to make the results more comparable to the Hsu and Serpell study (see Results and Discussion). Median CBARQ scores of probands and relatives were compared with Mann–Whitney *U* tests.

Shortened CBARQ Questions

We designed a shortened version of the CBARQ (sCBARQ), in which only one question addressed each Hsu and Serpell factor (see Fig. 2 for one example and the online supplement 1 for a complete list of questions). Two types of shortened CBARQ questions were made that differed in the time frame addressed. The first type of shortened CBARQ questions addressed the behavior of the dog in the months prior to its first participation in the project (Fig. 1). These will be referred to as ''$sCBARQ_0$ questions''. The second type of shortened CBARQ questions addressed the behavior of the dog in the recent past. These will be referred to as ''$sCBARQ_1$ questions''. Table 2 provides an overview of the question types that were included in questionnaires for the different groups of dogs.

Shortened CBARQ Scores: Comparison with CBARQ Scores and Reliability

All questionnaires about living dogs (192 dogs) contained both $sCBARQ_1$ questions and CBARQ items

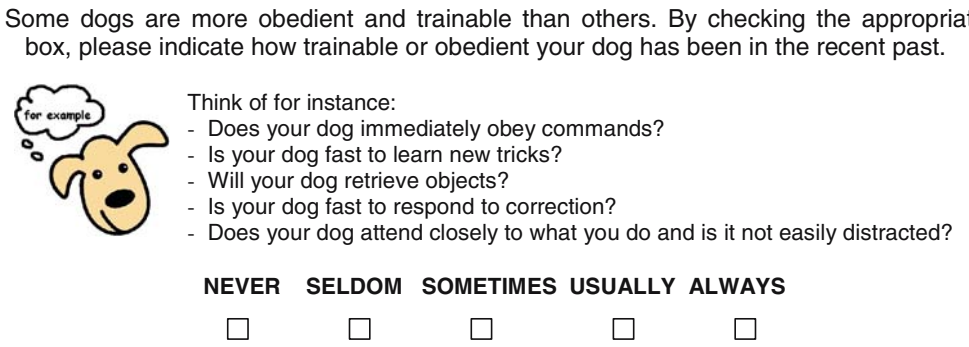

Fig. 2 An example of a $sCBARQ_1$ question. Eight questions about training and obedience have been condensed into one. The original eight questions are listed in the appendix of this paper

(Table 2). We used these questionnaires for calculations of linear regression of CBARQ scores on $sCBARQ_1$ scores. We compared linear, quadratic and cubic models, and linear models provided the best description of the relationship between the scores in all traits. For subsequent analyses, both $sCBARQ_0$ and $sCBARQ_1$ scores were converted using the regression formulas in order to make them more comparable to CBARQ scores.

The reliability of $sCBARQ_0$ scores was examined in group 1 dogs by comparison with data that were collected in the personal interview with the owner at the time of testing. These personal interview data contained information about five behavioral traits: stranger-directed aggression, owner-directed aggression, dog-directed aggression, trainability, and nonsocial fear. Questions about aggressive behavior and nonsocial fear were answered on a binary scale in the personal interview, e.g. ''Is your dog aggressive towards strangers or not?'' Trainability was scored on a 3-point scale, i.e. good, average or bad. Mann–Whitney *U* tests or Kruskall–Wallis tests were used to compare the scores.

Factor Analysis of the Aggression Test

Details about the aggression test procedure and the subjects can be found in a previous paper (van den Berg et al. 2003a). The subtests are listed in the online supplement 2 of the present paper. Subtests 1, 2, 3, and 22 were not included in the analyses because their standardization was moderate and the behavior of the dogs was sometimes poorly visible on tape. Subtest 4 and 5 (both tug-of-war) were excluded because aggressive behavior in these subtests should probably be interpreted as play (see van den Berg et al., 2003a).

Total frequencies of snapping, attacking and threatening behaviors (Table SI in the online supplement 2) in a subtest were summed to obtain ''aggression scores per subtest''. Factor analysis was performed on aggression scores in subtest 6–21. We extracted three factors (based on the scree test) and rotated the solution with the varimax method. We also performed factor analysis on fear scores per subtest (i.e. the sum of fearful behavioral elements observed in a subtest, see Table SII in the online supplement 2). Here, we extracted factors with eigenvalues over 1 and rotated the solution with the varimax method.

Comparison of Aggression Test Scores with $sCBARQ_0$ Scores

Three aggression test scores were calculated. The ''dog-directed aggression test score'' was the sum of aggression scores in subtest 15–19. The ''stranger-directed aggression test score'' was the sum of aggression scores in subtest 9–12, 20, and 21. The ''possessive aggression test score'' was the sum of aggression scores in subtest 7, 8, and 12–14. Both aggression test scores and $sCBARQ_0$ scores were available for 70 Golden Retrievers. We compared these scores by calculating Spearman's rank correlation coefficients with adjustments for tied ranks.

Statistical Tests

SPSS software was used for all statistical analyses. The significance level α was set at 0.05. The sharper Bonferonni procedure of Hochberg (1988) was used to adjust for multiple testing within each group of tests.

Results and Discussion

Response Rates

Response rates were very high for the majority of CBARQ items (median 99.5%). Five items had response rates below 92%: four items about familiar dog aggression (response rate 55%) and one item about fear reactions when having claws clipped by a household member (78%). These low response rates were due to many owners that have only one dog and/or that do not clip the claws of their dog. Response rates for individual dogs ranged from 86% to 100% (median 100% when the five items with response rates below 92% were excluded). Response rates for shortened CBARQ questions were 100%.

Factor Analysis

Principal factor analysis was used to group 71 CBARQ items in 10 factors that explained 58% of the total variance in item scores (Table 3). Items from the category ''aggression'' were grouped in four factors, which were labeled ''stranger-directed aggression'' (SDA), ''owner-directed aggression'' (ODA), ''dog-directed aggression'' (DDA) and ''chasing'' (CHASE). The CHASE factor also contained item 64 from ''excitability'' (excitement when the doorbell rings) and items from the category ''miscellaneous'' (dog chases cats, birds, or other animals). The majority of items from the category ''fear and anxiety'' were grouped in three factors: ''stranger-directed fear'' (SDF), ''nonsocial fear'' (NSF), and ''dog-directed fear'' (DDF). Items 43 (fear of veterinarian), 50 (fear when groomed or bathed), and 51 (fear when having feet toweled) loaded mainly on ODA, NSF, and SDF. Items from the

Table 3 Results of factor analysis on 71 CBARQ questionnaire items for 184 dogs

Hsu and[a] Serpell factor	CBARQ[a] item	SDA[b] (8.1%)	ODA[b] (7.2%)	AAS[b] &EX(7.0%)	NSF[b] (5.9%)	TRAIN[b] (5.7%)	SDF[b] (5.6%)	SRB[b] (5.3%)	DDA[b] (4.7%)	DDF[b] (4.5%)	CHASE[b] (4.3%)	Communality
Stranger-directed aggression	10	0.76					*0.32*					0.73
	11	0.65					*0.38*					0.60
	12	0.48										0.45
	15	0.66										0.55
	16	0.75										0.60
	18	0.59										0.56
	20	0.68										0.69
	21	0.68					*0.46*					0.73
	22	0.72										0.61
	28	0.55					*0.30*					0.56
Owner-directed aggression	9		0.56									0.59
	13		0.70									0.64
	14		0.63									0.47
	17		0.73									0.70
	19		0.71									0.70
	25		0.67									0.52
	30		0.62									0.53
	31		0.74									0.70
Stranger-directed fear	36						0.64					0.66
	37						0.66			*0.31*		0.66
	39						0.67					0.58
	40	*0.35*					0.74					0.77
Trainability	1					0.73						0.58
	2					0.73						0.57
	3					0.75						0.62
	4					0.79						0.64
	5					0.61						0.43
	6					0.56						0.42
	7				*−0.30*	0.53						0.50
	8					0.55						0.39
Separation-related behaviors	54						*0.31*	0.62				0.53
	55							0.65				0.52
	56							0.62				0.57
	57							0.71				0.55
	58							0.63				0.55
	59							0.82				0.71
	60*											0.38
	61							0.35				0.26
Excitability	62			0.59								0.57
	63			0.59	*0.40*							0.60
	64	*0.33*									0.43	0.53
	65			0.55								0.44
	66			0.51								0.43
	67			0.58								0.57

Table 3 continued

Hsu and[a] Serpell factor	CBARQ[a] item	SDA[b] (8.1%)	ODA[b] (7.2%)	AAS[b] &EX(7.0%)	NSF[b] (5.9%)	TRAIN[b] (5.7%)	SDF[b] (5.6%)	SRB[b] (5.3%)	DDA[b] (4.7%)	DDF[b] (4.5%)	CHASE[b] (4.3%)	Communality
Attachment/attention seeking	68			0.48								0.36
	69			0.73								0.64
	70			0.77								0.64
	71			0.75								0.63
	72			0.47								0.47
	73			0.61								0.50
Nonsocial fear	38				0.72							0.65
	41				0.56		*0.31*					0.50
	42				0.75							0.63
	44				0.58							0.40
	47				0.50							0.53
	48				0.75							0.70
Chasing	27	*0.39*									0.41	0.49
	74										0.84	0.75
	75										0.74	0.62
	76										0.79	0.69
Dog-directed aggression and fear	23								0.81			0.78
	24								0.79			0.74
	26								0.74			0.71
	29								0.71			0.59
	45									0.83		0.77
	46									0.80		0.70
	52						*0.32*			0.65		0.60
	53									0.78		0.68
Pain sensitivity	43		*0.31*		0.45							0.52
	50		*0.34*				0.40	*0.35*				0.55
	51		*0.52*				0.55					0.71
Cronbach's α (nr of dogs)[c]		0.90(180)	0.87(169)	0.86(185)	0.82(182)	0.82(184)	0.83(189)	0.76(189)	0.88(178)	0.86(176)	0.78(188)	
Cronbach's α excluding dogs with only zero's (nr of dogs)[c]		0.86(98)	0.80(67)	0.86(185)	0.78(152)	0.82(184)	0.74(72)	0.64(66)	0.85(138)	0.76(84)	0.72(171)	

[a]The first two columns show the Hsu and Serpell factor solution (2003)

[b]Column three through 12 depict our own factor solution. Numbers in brackets represent the percentage of variance explained by our factors. Loadings between −0.3 and 0.3 are not shown and cross-loadings are printed in italics. SDA = stranger-directed aggression; ODA = owner-directed aggression; AAS&EX = attachment, attention seeking and excitability; NSF = non-social fear; TRAIN = trainability; SDF = stranger-directed fear; SRB = separation-related behaviors; DDA = dog-directed aggression; DDF = dog-directed fear; CHASE = chasing

[c]The two rows at the bottom of the table show Cronbach's alpha for our factors. Dogs with missing values on one or more items were excluded from the calculations; numbers in brackets represent the number of dogs included. Alpha was calculated both for the complete group of dogs (upper row) and for dogs with a higher score than zero on at least one of the items in the factor (lower row)

*Item 60 had factor loadings between −0.3 and 0.3 on several factors and is therefore not classified in any of the factors

categories ''attachment and attention-seeking'' and ''excitability'', with the exception of item 64, were grouped in one factor, which was labeled ''attachment, attention-seeking, and excitability'' (AAS&EX). The ''separation-related behavior'' items formed one factor (SRB), but item 60 (destructive behavior) and 61 (loss of appetite) loaded very low on this factor. Items from the category ''training and obedience'' were grouped in one factor (TRAIN). Some items had cross-loading on other factors (e.g. SDA and SDF). Communalities (i.e. the variance in an item accounted for by the ten factors) were moderately high for most items (see last column in Table 3; Tabachnick and Fidell 2001).

The factor solution presented here is very similar to the one obtained by Hsu and Serpell (2003). This stability of the factor structure is remarkable for three reasons. First, the subjects in our study were a selected group: all dogs were Golden Retrievers that had aggression problems when they first participated in our project, or that were related to a dog with aggression problems. Second, we did not use the same set of items for the analysis: the CBARQ contains several new items that Hsu and Serpell did not include in their factor analysis. This is likely to affect the correlation matrix used for factor analysis. Third, the stability is remarkable because the number of dogs that was used in our factor analysis (184) is low compared to the number of items included (71). A variable-to-case ratio of 1:5 is often used as a lower boundary to create a stable correlation matrix. Taken together, these findings provide a firm support for the stability of the factor structure proposed by Hsu and Serpell across various populations of dogs.

We did observe some differences between our factor solution and the one presented by Hsu and Serpell (2003). First, the distinct factors DDA and DDF of our study were merged into a single ''dog-directed aggression and fear'' factor in the Hsu and Serpell solution. Second, the factor AAS&EX was split in a separate ''attachment/attention-seeking behavior'' factor and an ''excitability'' factor by Hsu and Serpell. Item 64 (excitement when the doorbell rings) loaded on ''excitability'', instead of ''chasing'' in the Hsu and Serpell solution. We performed several exploratory factor analyses on our dataset by in-and excluding dogs and CBARQ items. The association between item 64 and CHASE was not stable. We decided to include the item in the AAS&EX factor in further analyses. Hsu and Serpell grouped items 43 (fear of veterinarian), 49 (fear when having claws clipped), and 50 (fear when groomed or bathed) in a factor ''pain sensitivity''. This factor had low internal consistency reliability (Cronbach's $\alpha = 0.60$) in the study by Svartberg (2005). Associations between pain sensitivity items and our factors were not stable. We therefore decided to exclude item 43, 49, and 50 from further analyses.

We performed a second factor analysis on 36 items from the six aggression and fear factors of the initial solution (SDA, ODA, DDA, SDF, NSF, and DDF) in order to study the correlations between these items in more detail. The items were grouped in six factors that explained 63% of the variance in item scores (Table 4). The items of the factors ODA, NSF, DDA, and DDF behaved similarly as in the previous solution. SDA items 10, 11, and 21 (aggression when approached or petted by an unfamiliar adult or child) now loaded high on the SDF factor. These three items already had cross-loading on SDF in the previous solution. The remaining SDA items loaded on the main SDA factor, which seems to represent territorial aspects of SDA (aggression when strangers approach the dog while it is in the owner's car, when strangers approach the owner, and when mailmen, joggers or other strangers approach the home while the dog is in the yard).

Hsu and Serpell (2003) did not mention correlations between SDA and SDF items. However, in their earlier guide dog study, SDA and SDF items were highly correlated (Serpell and Hsu 2001). We can conclude that, at least in some dogs, aggression toward strangers and fear of strangers are associated. The suggestion that the aggressive behavior towards strangers of some of our subjects is motivated by fear is supported by earlier reports that the familial aggression in Golden Retrievers is fear-motivated (Galac and Knol 1997; Knol et al. 1997). In the same line of reasoning, we interpret the correlations between the ODA factor and items 50 and 51 (fear when groomed, bathed, or having feet toweled) as a suggestion that the aggressive behavior towards the owner of some of the subjects is also motivated by fear.

Reliability of the Factors

Cronbach's alpha values ranged from 0.76 to 0.90 for our factors (Table 3), indicating that they are reliable. Alpha was 0.81 for items 32–35 (number of dogs = 102), suggesting that these items measure a single latent construct (familiar dog aggression). We also performed Cronbach's alpha calculations excluding dogs with a score of zero on all factor items because such dogs do not provide much information about the relationships between the items. Alpha was lower than for the complete group of dogs, but still higher than 0.7 in the majority of factors (Table 3). We therefore conclude that the factors are reliable in these dogs as well.

Table 4 Result of factor analysis on 36 CBARQ aggression and fear items for 184 dogs

Factor in first solution[a]	CBARQ item[a]:	SDA-T[b](13.1%)	ODA[b](12.1%)	SDA&F[b](10.9%)	NSF[b](9.6%)	DDA[b](9.1%)	DDF[b](8.4%)	Communality
Stranger-directed aggression	10	0.67		*0.46*				0.72
	11	*0.49*		0.57				0.61
	12	0.48				*0.31*		0.42
	15	0.71						0.56
	16	0.69						0.60
	18	0.67						0.56
	20	0.78						0.73
	21	*0.49*		0.65				0.74
	22	0.78						0.68
	28	0.66						0.54
Owner-directed aggression	9		0.57					0.47
	13		0.77					0.66
	14		0.60					0.39
	17		0.81					0.78
	19		0.78					0.76
	25		0.64					0.48
	30		0.59					0.42
	31		0.78					0.68
Stranger directed fear	36			0.72				0.65
	37			0.78				0.72
	39			0.68				0.57
	40			0.85				0.83
Nonsocial fear	38				0.79			0.70
	41				0.62			0.51
	42				0.81			0.71
	44				0.62			0.42
	47				0.54		*0.30*	0.51
	48				0.82			0.74
Dog-directed aggression	23					0.87		0.81
	24					0.85		0.77
	26					0.78		0.68
	29					0.71		0.59
Dog-directed fear	45						0.84	0.75
	46						0.81	0.70
	52			*0.34*			0.67	0.60
	53						0.81	0.70

[a]The first two columns show the factors that were found in the first analysis (Table 3)

[b]Column three through eight depict the new factor solution. Factor labels are presented above the columns and numbers in brackets represent the percentage of variance explained by the factors. Loadings between −0.3 and 0.3 are not shown and cross-loadings are printed in italics. SDA-T = territorial aspects of stranger-directed aggression; ODA = owner-directed aggression; SDA&F = stranger-directed aggression and fear; NSF = non-social fear; DDA = dog-directed aggression; DDF = dog-directed fear

Although the above results provide firm evidence for the reliability of CBARQ factors, we would like to add one suggestion for future research. Aggression is evaluated on a 5-point qualitative rating scale in the CBARQ (i.e. 0 = no aggression, 1–3 = moderate aggression, and 4 = serious aggression). Some Golden Retriever owners experienced difficulties answering these items because their dog would sometimes behave aggressively in a particular situation, while showing no signs of aggression at other times in the same situation. We expect such confusion of the owners to lead to decreased inter-rater reliability of the CBARQ scores. In the guide dog study of Serpell and Hsu, aggression items were scored on a frequency scale instead of a qualitative scale (e.g. ''How often did your dog growl when approached by an unfamiliar adult in the recent past?''). This type of scale may be more appropriate for evaluating aggressive behavior because it will introduce a higher inter-rater reliability. This should be investigated in the future.

Variation in CBARQ Scores

We calculated ''CBARQ scores'' as the mean of CBARQ items that were grouped in a factor of the solution from Table 3 (see Methods). SDA scores of the 192 Golden Retrievers ranged from 0 to 2.8, with a mean of 0.34 (Table 5). ODA scores ranged from 0 to 2.9, with a mean of 0.32; and DDA scores ranged from 0 to 4, with a mean of 0.92. Dogs that were originally recruited as probands scored significantly higher than dogs that were recruited as relatives on all three types of aggression ($P < 0.0001$ for SDA, ODA, and DDA; tested with Mann–Whitney U tests). Descriptive statistics of the other CBARQ scores can be found in Table 5.

The frequency distributions of SDA, ODA, and DDA scores were skewed to the right (Fig. 3). Apparently, the majority of dogs had low aggression scores, in spite of the fact that almost half of them had been referred to our clinic for aggression problems several years before the questionnaire was filled out. We can consider two explanations for these low aggression scores. First, there was an average gap of 4.3 years between the first participation and the time when the owner filled out the CBARQ. Many aggression problems that were present at the time of first participation have diminished over time. This is dealt with in detail later in this paper. Another possible explanation for the low CBARQ scores is that CBARQ contains a limited number of aggression-eliciting situations. It is possible that some other situations that provoke aggression in the Golden Retrievers are not present in the questionnaire. In order to investigate the plausibility of this latter explanation, we studied answers that owners gave to the open question ''Are there any other situations in which your dog is sometimes aggressive?''. No consistent pattern could be deduced from the answers of the Golden Retriever owners, indicating that the CBARQ encompasses the most important aggression-eliciting situations for our dogs. Low aggression scores can therefore not be explained by the absence of important aggression-eliciting situations in the CBARQ.

Phenotypic variation within families is a prerequisite for molecular and quantitative genetic studies. Figure 4 depicts CBARQ scores in a pedigree containing 42 Golden Retrievers that were included in

Table 5 Descriptive statistics of CBARQ scores in 192 Golden Retrievers

CBARQ score[a]	Complete group					Probands only		
	Number of dogs	Minimum	Maximum	Mean	SD	Number of dogs	Mean	SD
SDA	192	0	2.8	0.34	0.52	82	0.56	0.59
ODA	192	0	2.9	0.32	0.60	82	0.61	0.77
AAS&EX	192	0.080	3.4	1.6	0.76	82	1.9	0.80
NSF	192	0	3.7	0.83	0.81	82	1.2	0.95
TRAIN	192	0.50	4.0	2.8	0.69	82	2.7	0.70
SDF	192	0	4.0	0.23	0.60	82	0.35	0.68
SRB	189	0	1.6	0.16	0.32	81	0.24	0.41
DDA	192	0	4.0	0.92	1.0	82	1.3	1.2
DDF	192	0	3.3	0.49	0.71	82	0.52	0.74
CHASE	191	0	4.0	1.4	1.0	82	1.4	1.1
FDA	109	0	3.5	0.60	0.82	37	1.0	1.1

[a]SDA = stranger-directed aggression; ODA = owner-directed aggression; AAS&EX = attachment, attention seeking and excitability; NSF = non-social fear; TRAIN = trainability; SDF = stranger-directed fear; SRB = separation-related behaviors; DDA = dog-directed aggression; DDF = dog-directed fear; CHASE = chasing; FDA = familiar dog aggression

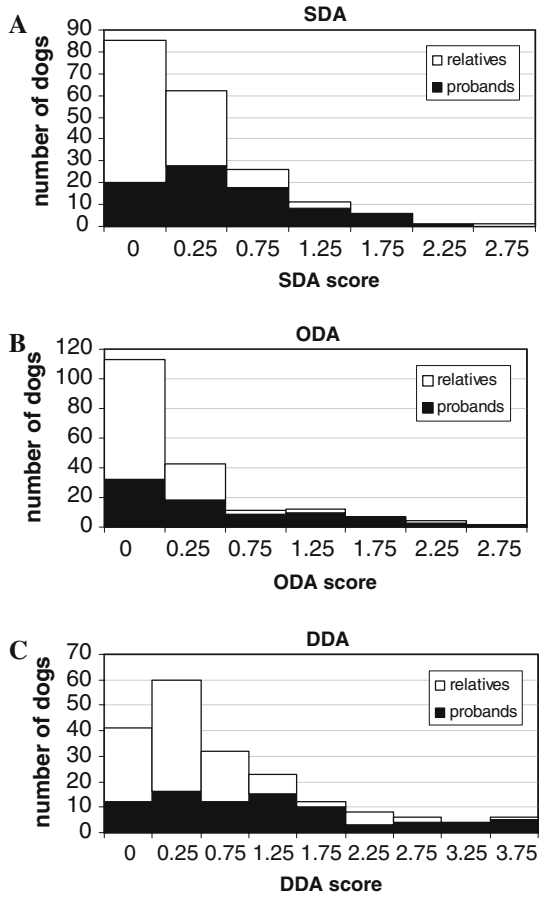

Fig. 3 Frequency distributions of CBARQ aggression scores in 192 Golden Retrievers. The height of the bars represents the absolute number of dogs with a particular stranger-directed (A), owner-directed (B) or dog-directed (C) aggression score. Black parts of the bars represent probands and white parts represent relatives. Numbers underneath the bars represent class marks. Note that the size of the first class differs from the others: this class contains CBARQ scores of 0

the present study. There is considerable variation in aggression scores within this family. The figure also illustrates that there is a co-occurrence of the different types of aggression in many dogs: of 22 dogs that had above-average scores on one type of aggression, 13 also scored above the mean for another type of aggression. It has been recognized by other authors that dogs regularly exhibit more than one type of aggression (Beaver 1993; Landsberg et al., 2004; Overall 1997). Note that there is no particular type of aggression that is clearly the most prevalent in this family. Both the co-occurrence of different types of aggression within single dogs and the presence of several types of aggression within this pedigree of closely related dogs may be due to genetic factors influencing all traits, to environmental factors influencing all traits, or to both.

Shortened CBARQ Scores: Comparison with CBARQ Scores and Reliability

We designed a shortened version of the CBARQ for two purposes. First, we wanted to obtain behavioral scores for deceased dogs and we felt it was inappropriate to send the long CBARQ to owners of deceased dogs. Second, we wished to investigate behavioral changes over time. Before we used shortened CBARQ questions to this end, we investigated the relationship between CBARQ scores and shortened CBARQ scores. We therefore performed linear regression of CBARQ scores on $sCBARQ_1$ scores. The coefficients are presented in Table 6. The coefficient of determination (R^2) ranged from 0.43 to 0.65, indicating that 43–65% of the variation in CBARQ scores is explained by $sCBARQ_1$ scores. For subsequent analyses, $sCBARQ_0$ and $sCBARQ_1$ scores were converted into the values predicted by the linear regression formulas in order to make them more comparable to CBARQ scores. Note that homogeneity of variances is an assumption of linear regression and this assumption was not met in our data. However, this violation of the assumptions only has consequences for the test of significance (the P value will be too low). R^2, the intercept and the slope will be unbiased (Tate and Wongbundhit 1983).

The long recall period for $sCBARQ_0$ questions (on average 4.3 years) might result in a decline of the quality of the data (Mathiowetz 2000). We investigated the reliability of $sCBARQ_0$ scores by comparing them with data that were collected in the personal interview with the owner at the time of first participation with Mann–Whitney U or Kruskal–Wallis tests. Dogs that were aggressive towards strangers according to the personal interview had significantly higher $sCBARQ_0$ SDA scores than dogs that were not aggressive towards strangers according to the personal interview ($P < 0.0001$; $n = 115$). Similar results were obtained for ODA ($P < 0.0001$; $n = 115$) and DDA ($P < 0.0001$; $n = 117$). We also found a significant difference in $sCBARQ_0$ NSF scores between dogs that were afraid of noises according to the personal interview and those that were not ($P = 0.003$; $n = 93$). Scores on the $sCBARQ_0$ trainability question also corresponded with the personal interview ($P = 0.02$; $n = 60$). The better correspondence between personal interview data and aggression scores than between personal interview data and NSF or TRAIN scores was expected because aggressive attacks are very salient for owners and salient events are thought to be less subject to errors of recall decay (Mathiowetz 2000). It was concluded that the five $sCBARQ_0$ scores are reliable in spite of the long recall period.

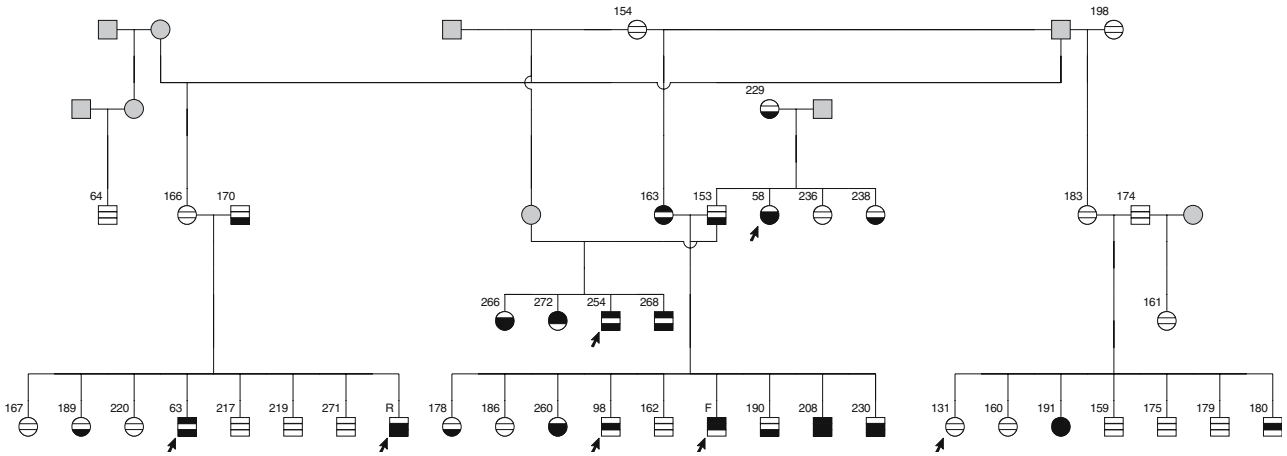

Fig. 4 Pedigree containing 42 subjects of the present study. Squares represent males, circles represent females, and arrows mark probands. Numbers above the symbols are identification numbers from our database. Each symbol contains three behavioral phenotypes: the upper part of the symbol represents the stranger-directed aggression score (SDA), the central part represents the owner-directed aggression score (ODA), and the bottom part represents the dog-directed aggression score (DDA). Phenotypes are presented relative to mean of the complete group of 192 Golden Retrievers (0.34 for SDA, 0.32 for ODA, and 0.92 for DDA); a black shade is used if the dog has an aggression score above the mean of the complete group and a white shade is used for scores equal to or below the mean. Grey symbols represent ancestors from which we have no behavioral information. We have omitted all siblings from which behavioral information was not available. The phenotypes of dog R and 183 are based on shortened CBARQ questions

Table 6 Linear regression coefficients for 11 behavioral traits

Factor:[a]	R^2:	Intercept:	Slope:
SDA	0.45	0.13	0.38
ODA	0.45	0.12	0.36
AAS[b]	0.47	0.31	0.59
EX[b]	0.47	0.68	0.51
NSF	0.58	0.21	0.55
TRAIN	0.53	1.1	0.58
SDF	0.62	0.034	0.71
SRB	0.43	0.071	0.32
DDA	0.65	0.29	0.73
DDF	0.59	0.18	0.63
CHASE	0.60	0.38	0.65

[a]SDA = stranger-directed aggression; ODA = owner-directed aggression; AAS&EX = attachment, attention seeking and excitability; NSF = non-social fear; TRAIN = trainability; SDF = stranger-directed fear; SRB = separation-related behaviors; DDA = dog-directed aggression; DDF = dog-directed fear; CHASE = chasing

[b]Linear regression was performed separately for AAS and EX because there were two separate $sCBARQ_1$ questions addressing these traits

Behavioral Changes in the Course of Time and their Implications for Phenotyping

We analyzed changes in aggressive behavior over time by comparing $sCBARQ_0$ scores to $sCBARQ_1$ scores in the living dogs of group 1. $sCBARQ_0$ scores were subtracted from $sCBARQ_1$ scores; a negative value therefore represents a decrease in aggression in the course of time. We were mainly interested in changes in aggression in dogs that were aggressive in the past. Therefore, we split the group of dogs in two for each analysis: dogs that did not show the particular type of aggression at all in the past (i.e. score = 0; ''non-aggressive dogs'' in Fig. 5) and dogs that showed at least some aggression (score >0; ''aggressive dogs'' in Fig. 5). Twenty-one out of 41 dogs (51%) that showed at least some aggression towards strangers in the past had become less aggressive over time (Fig. 5A). Twenty-nine out of 39 dogs (74%) that showed some aggression towards their owner had become less aggressive (Fig. 5B). Twenty-seven out of 49 dogs (55%) that showed some aggression towards other dogs had become less aggressive in the course of time (Fig. 5C).

Owners were also asked whether they could explain behavioral changes. Forty-one owners gave one or several answers to this question. The most frequent answer (28 times) was ''I now avoid situations in which problem behavior is likely to occur.'', followed by ''I feel I had more control over the dog in the recent past.'' (13 times). The increased age of the dog was also mentioned several times as an explanation. Owners of deceased dogs of group 1 were also asked whether the behavior of their dog changed after the first participation. Six owners reported a behavioral change; in five of these dogs the aggressive behavior had increased and they were euthanized as a result.

The question is now how to use these findings in our molecular genetic studies. One option is to give more

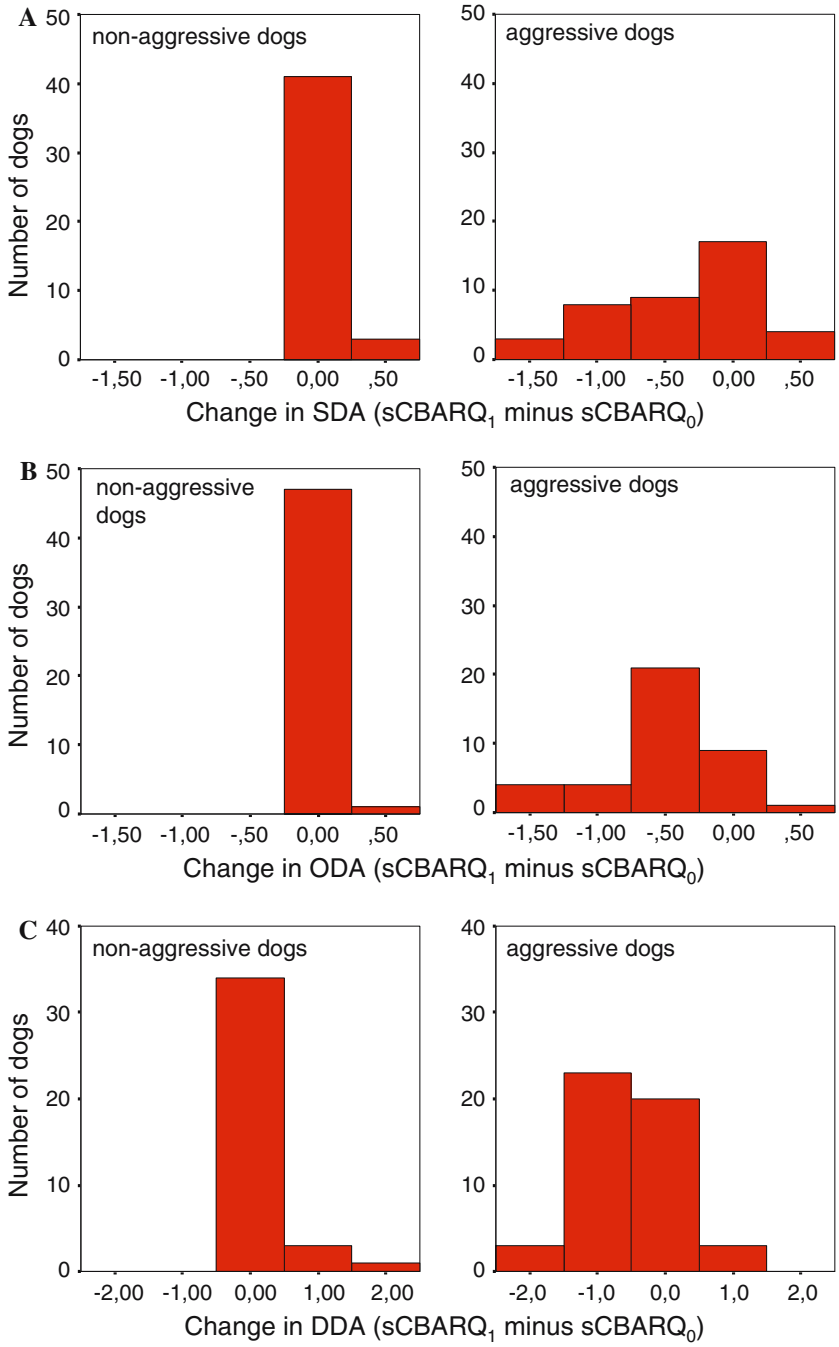

Fig. 5 Changes in aggressive behavior over time. A. stranger-directed aggression (SDA) B. owner-directed aggression (ODA) C. dog-directed aggression (DDA). Scores on $sCBARQ_0$ questions were subtracted from $sCBARQ_1$ questions, i.e. negative values represent a decrease in aggressive behavior. For each type of aggression, the group of dogs was split in two. The left histogram contains the results for dogs that had the lowest possible score on the type of aggression depicted. For example, the left histogram of Figure A represents dogs with a $sCBARQ_0$ stranger-directed aggression score of 0. The right histogram represents dogs that showed at least some aggression, e.g. a $sCBARQ_0$ SDA score of higher than 0

weight to dogs that kept the same level of aggression over time. However, a decrease in the tendency to behave aggressively does not necessarily mean that genetics plays a lesser role in etiology of the aggression of the dogs concerned. The changes might be caused by environmental factors (which is supported by the explanations given by the owners) and the absence of change may reflect the absence of such environmental forces.

Shortened CBARQ Scores as Behavioral Phenotypes

Decreases in aggressive behavior over time are a valid explanation for the low CBARQ aggression scores that we mentioned earlier in this paper. We would expect to obtain higher CBARQ aggression scores if we had measured them at the time of first participation. By using $sCBARQ_0$ questions for group 1 dogs and $sCBARQ_1$ questions for group 2 dogs, we can obtain an estimation of CBARQ aggression scores at the time of first participation. Descriptive statistics of these shortened CBARQ aggression scores are listed in Table 7. As expected, mean shortened SDA, ODA, and DDA scores at first participation were higher than the corresponding mean CBARQ scores (presented in Table 5). Dogs that were recruited as probands scored significantly higher than dogs that were recruited as relatives on all three types of aggression ($P < 0.0001$ for SDA, ODA, and DDA; tested with Mann–Whitney U tests).

Sex Differences in Aggression Scores

Eighty out of 110 (73%) probands in our study group were male. The proportion of males among relatives was only 47%. The increased proportion of males in the probands group ($P < 0.001$, tested with a χ^2 test) is in accordance with findings of other researchers. Several studies have reported an overrepresentation of male dogs among aggressive patients of behavioral clinics (Borchelt, 1983; Reisner 1997). Forty-nine of the male probands (61%) had been castrated at the time the questionnaire was filled out. Only 14 out of 55 male relatives (25%) had been castrated. This increased prevalence of castrated dogs among male probands compared to relatives ($P < 0.0001$, tested with a χ^2 test) probably results from the common practice of castrating male aggressive dogs in the hope that they will become less aggressive.

Surprisingly, CBARQ aggression scores did not differ significantly between male and female probands ($P = 0.15$, $P = 0.44$, and $P = 0.87$ for SDA, ODA, and DDA, respectively; tested with Mann–Whitney U tests) or male and female relatives ($P = 0.086$, $P = 0.65$, and $P = 0.52$ for SDA, ODA, and DDA, respectively). Similar findings were obtained for shortened CBARQ aggression scores at the time of first participation ($P = 0.075$, $P = 0.10$, and $P = 0.79$ for SDA, ODA, and DDA in probands and $P = 0.18$, 0.70, and 0.63 for SDA, ODA, and DDA in relatives). We also compared CBARQ aggression scores between the four reproductive classes (intact males, castrated males, intact females, and castrated females) with Kruskall–Wallis tests. There were no significant differences in SDA, ODA, and DDA scores between the four classes among probands ($P = 0.50$, $P = 0.57$, and $P = 1.0$ for CBARQ scores and $P = 0.28$, $P = 0.38$, and $P = 0.93$ for shortened CBARQ scores). CBARQ aggression scores of intact male, castrated male, intact female, and castrated female relatives did not differ significantly either ($P = 0.063$, $P = 0.059$, and $P = 0.57$, respectively for SDA, ODA, and DDA). However, there was a trend towards lower SDA scores in intact male relatives compared to the three other classes. In addition, there was a trend towards higher ODA scores in castrated males compared to the three other classes. These trends were also observed for shortened CBARQ scores in relatives. We have no explanation for the lower SDA scores in intact males. The high ODA scores of castrated males compared to intact males most likely result from the common practice of castrating aggressive dogs in the hope that they will become less aggressive. Similar observations on the relationship between the reproductive status and aggressive behavior have been made by Podberscek and Serpell (1996) in English Cocker Spaniels and Reisner et al. (2005) in English Springer Spaniels. In the study of Podberscek and Serpell, the significant positive association between neutering and aggression largely disappeared when dogs neutered specifically because they had been aggressive were removed from the analysis. Reisner et al. (2005) observed that castration was often the result of aggressive behavior rather than a contributing cause, especially in male dogs.

Table 7 Descriptive statistics of shortened CBARQ aggression scores of 228 Golden Retrievers at the time of first participation

Shortened CBARQ score[a]	Complete group					Probands only		
	Number of dogs	Minimum	Maximum	Mean	SD	Number of dogs	Mean	SD
SDA	228	0.13	1.7	0.46	0.46	110	0.74	0.51
ODA	228	0.12	1.6	0.51	0.54	110	0.87	0.57
DDA	228	0.29	3.2	1.1	0.92	110	1.5	1.0

[a]SDA = stranger-directed aggression; ODA = owner-directed aggression; DDA = dog-directed aggression

Factor Analysis of the Aggression Test

Our factor analysis of CBARQ items resulted in the three aggression types SDA, ODA, and DDA (Table 3). In a previous study, we analyzed the behavior of 83 Golden Retrievers in an aggression test (van den Berg et al. 2003a). Behavioral scores were then obtained by summing frequencies of aggressive behavioral elements that were displayed in the subtests. We now investigated whether the subtests of the aggression test can be grouped into classes corresponding to CBARQ aggression types by performing factor analysis on aggression scores per subtest. Three factors were extracted, explaining 64.3% of the variance in subtest scores (Table 8). The first factor contained subtest 15–19, which involved confrontations of the Golden Retriever with other dogs. The factor was labeled ''dog-directed aggression''. Subtest 6 (squeezing groins) also loaded on this factor. Subtests 9–12, 20, and 21 loaded high on the second factor. These subtests involve confrontations with strangers and the factor was thus labeled ''stranger-directed aggression''. The third factor contained items 7 (pull feeding bowl by test person), 8 (pull feeding bowl by owner), 13 (cornering), and 14 (threatening the owner). Item 18 (feeding in presence of other dog) correlated with the third factor and item 12 (hitting) loaded approximately equally on factor two and three. This third factor was labeled ''possessive aggression''. Cronbach's alpha values for the factors were 0.77 (0.79 when subtest 6 was excluded), 0.80, and 0.79 respectively.

The first two factors that we extracted closely resemble the two CBARQ factors dog-directed aggression and stranger-directed aggression in spite of the fact that we did not select subtests for their comparability to CBARQ items. This provides additional support for the reliability of these CBARQ factors. Subtest 6 (squeezing groins) unexpectedly loaded on the dog-directed aggression factor. We expected this subtest to represent owner-directed aggression, so correlations with the third factor would seem more logical. This subtest might be comparable to ''pain sensitivity'' CBARQ items, which failed to behave consistently in our factor analysis of the CBARQ items.

The third type of aggression in CBARQ, owner-directed aggression, was not found in the aggression test dataset. We did find a factor containing food-related subtests and subtest 13 (cornering) and 14 (threatening the owner). We interpreted aggressive behavior of the dogs in the latter two subtests as protection of the owner. In functional classifications of canine aggression, possessive (or food-related) and protective (or territorial) aggression are distinguished (Borchelt and Voith 1996; Landsberg et al. 2004; Reisner 2003). Borchelt (1983) mentioned correlations between these aggression classes in clinical datasets. The present results confirm the presence of this correlation empirically.

Our factor analysis of CBARQ items resulted in the three fear types SDF, NSF, and DDF (Table 3). We performed a factor analysis on fear scores per subtest in order to find out whether subtests of the aggression test can be grouped into classes corresponding to CBARQ fear types. Two factors explaining 70% of the variance in subtest scores were extracted (Table 9). The first factor contained subtest 6, 9–17, and 19–21, while the second factor contained subtest 7 and 8 (food

Table 8 Result of factor analysis on aggression scores in subtest 6–21 of the aggression test for 83 dogs

Subtest	Factor			Communality
	DDA[a](23.2%)	SDA[a](20.7%)	PA[a](20.3%)	
6 (squeezing groins)	0.79			
7 (pull feeding bowl by test person)			0.81	0.66
8 (pull feeding bowl by owner)			0.88	0.79
9 (umbrella)		0.64		0.42
10 (strange woman)		0.81		0.72
11 (clapping)		0.67		0.52
12 (hitting)		0.59	*0.54*	0.64
13 (cornering)		*0.39*	0.64	0.56
14 (threatening the owner)		*0.38*	0.81	0.85
15 (cornering with dogs)	0.79			0.64
16 (dominant dog)	0.78		*0.39*	0.76
17 (owner pets other dog)	0.71			0.57
18 (feeding in presence of other dog)	0.74		*0.41*	0.72
19 (feeding bowl given to other dog)	0.75			0.57
20 (doll)		0.83		0.69
21 (dog mask)	*0.39*	0.62		0.54
Cronbach's α	0.77	0.80	0.79	

[a]Numbers in brackets represent the percentage of variance explained by the factors. Loadings between −0.3 and 0.3 are not shown and cross-loadings are printed in italics. DDA = dog-directed aggression; SDA = stranger-directed aggression; PA = possessive aggression

Table 9 Result of factor analysis on fear scores in subtest 6–21 of the aggression test for 83 dogs

Subtest	Factor		Communality
	THREAT[a](54.9%)	NO THREAT[a](15.0%)	
6 (squeezing groins)	0.83		
7 (pull feeding bowl by test person)		0.82	0.69
8 (pull feeding bowl by owner)		0.73	0.60
9 (umbrella)	0.90		0.84
10 (strange woman)	0.79	*0.37*	0.76
11 (clapping)	0.88		0.77
12 (hitting)	0.79		0.63
13 (cornering)	0.85		0.74
14 (threatening the owner)	0.84		0.79
15 (cornering with dogs)	0.87	*0.31*	0.86
16 (dominant dog)	0.78		0.69
17 (owner pets other dog)	0.57	*0.54*	0.61
18 (feeding in presence of other dog)		0.64	0.42
19 (feeding bowl given to other dog)	0.79		0.63
20 (doll)	0.87		0.78
21 (dog mask)	0.83		0.69
Cronbach's α	0.96	0.67	

[a]Numbers in brackets represent the percentage of variance explained by the factors. Loadings between −0.3 and 0.3 are not shown and cross-loadings are printed in italics.
THREAT = threatening subtests;
NO THREAT = non-threatening subtests

bowl), 17 (owner pets other dog), and 18 (feeding in presence of other dog). Subtests loading high on the first factor involve threatening of the dog and the factor was labeled ''threatening subtests''. The second factor contains more neutral stimuli and was thus labeled ''non-threatening subtests''. Cronbach's alpha values for the factors were 0.96 and 0.67 (including subtest 17) respectively.

The finding of three separate aggression test factors suggests that some dogs showed more aggression in specific groups of subtests than in others. A similar specialization was not observed when fear scores per subtest were analyzed. Here, we found a subdivision in threatening and non-threatening subtests. The dogs apparently did not make a consistent distinction between different types of stimuli (i.e. dogs or humans); dogs were either fearful or not fearful in all of these subtests. We expect this to be an artefact of the test: fearful behavior in the test might be a reflection of how impressed the dogs are by the test situation.

Comparison of Aggression Test Scores with sCBARQ$_0$ Scores

Three aggression test scores were calculated by summing aggression scores during subtests of each factor (e.g. ''dog-directed aggression test score'' = sum of aggression scores in subtest 15–19). We calculated Spearman's rank correlation coefficients for every possible combination of the three aggression test scores and the three sCBARQ$_0$ questions about aggression. We expected to find positive correlations between the stranger-directed aggression test score and the sCBARQ$_0$ question about SDA and between the dog-directed aggression test score and the sCBARQ$_0$ question about DDA. We might also expect a positive correlation between the possessive aggression test score and the sCBARQ$_0$ question about ODA, because some of the subtests of the possessive aggression factor resembled CBARQ items about ODA. All these correlations were found indeed (diagonal in Table 10). Lower but still significant positive correlations were found between aggression test scores and the non-corresponding sCBARQ$_0$ scores (off-diagonal values in Table 10). In other words, there was significant convergent validity (evidence of similarity between measures of theoretically related constructs), but poor discriminant validity (absence of correlation between measures of unrelated constructs) between aggression test scores and sCBARQ$_0$ scores.

We also found a significant agreement between owner-acknowledged information and aggression test

Table 10 Spearman's rank correlation coefficients of three aggression test scores (in rows) and three sCBARQ$_0$ aggression scores (in columns) from 70 dogs

Aggression test score[a]	sCBARQ$_0$ SDA score[b]	sCBARQ$_0$ ODA score[b]	sCBARQ$_0$ DDA score[b]
SDA	0.43*	0.26**	0.25**
PA	0.42*	0.36*	0.25**
DDA	0.34*	0.30**	0.45*

[a]SDA = stranger-directed aggression in the aggression test; PA = possessive aggression in the aggression test; DDA = dog-directed aggression in the aggression test

[b]SDA = stranger-directed aggression; ODA = owner-directed aggression; DDA = dog-directed aggression

*Correlation is significant at the 0.01 level (2-tailed)

**Correlation is significant at the 0.05 level (2-tailed)

scores in our previous study, in spite of the fact that there were many owner-acknowledged aggressive dogs that showed little aggression in the test (van den Berg et al. 2003a). In that study, behavioral scores were obtained by summing frequencies of aggressive behavioral elements that were displayed in the subtests and the owner-acknowledged information was derived from the personal interviews. Svartberg (2005) found no significant correlation between aggression in the Swedish Dog Mentality Assessment and the stranger-directed aggression CBARQ score in his dogs. It is hard to comment on the disagreement between our findings since the two studies cannot be compared because we used different behavioral tests, different questionnaires, and different subjects.

Several explanations can be given for the poor discriminant validity. First and most importantly, as we already showed in the section about variation in CBARQ scores, there frequently was a co-occurrence of different types of aggression within single dogs. This will result in indirect correlations between seemingly unrelated shortened CBARQ questions and aggression test scores. Second, the aggressive behavior observed in the aggression test might be a reflection of aggressiveness in unfamiliar situations, regardless of the exact type of stimulus involved. This explanation is line with the suggestion of Svartberg (2005) that aggression in the Swedish Dog Mentality Assessment reflects aggression towards novel stimuli. However, if aggression in our test would merely reflect aggression towards novel stimuli, we would not expect to find three different groups of subtests in the factor analysis. We would rather expect to find only one major aggression factor, similar to the one major fear factor. This hypothesis can therefore at most partially explain the poor discriminant validity.

The results presented above highlight two disadvantages of using aggression tests as a method for phenotyping. First, it seems that we were not able to elicit an important class of aggression in the test: owner-directed aggression. At first glance, the possessive aggression factor seems to include ODA, but Table 10 shows that possessive aggression test scores in fact correlated better with SDA in the CBARQ than with ODA. On logical grounds, it is to be expected that territorial aspects of SDA cannot be elicited in an artificial situation either. Second, fearful behavior in the aggression test was not object-specific. This suggests that fearful behavior in the test is a reflection of fear in unfamiliar situations and this may apply partially to aggression in the test as well. This may also explain our earlier observation that many Golden Retrievers that were aggressive according to their owner showed little or no aggression in the test (van den Berg et al. 2003a, b). We can conclude that, in spite of the positive correlations between aggression test scores and shortened CBARQ scores, the behavior of the dogs in the aggression test is likely to be not completely representative of their behavior in everyday life.

Conclusion

In summary, factor analysis of CBARQ items revealed a nearly identical factor structure as found in previous studies. The internal consistency reliability of the factors was high. In addition, two out of three CBARQ aggression factors could also be found in the aggression test data that we collected earlier. CBARQ aggression scores displayed substantial variation within the Golden Retriever families, which is a prerequisite for genetic studies. Thus, the behavioral scores derived from the CBARQ provide a promising tool for future research. We consider the CBARQ a more useful instrument for phenotyping than the aggression test because the CBARQ encompasses a higher number of everyday life situations and because behavior in the aggression test may not be representative of the dog's behavior in everyday life. Genetic parameters of various CBARQ based behavioral scores will now be investigated in quantitative genetic studies. These studies will give more insight into the usefulness of the scores for molecular genetic studies.

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Appendix

Appendix table: The canine behavioral assessment and research questionnaire (CBARQ)

Category		CBARQ item	
Training and obedience	Dog	1	returns immediately when called when off leash
		2	obeys the ''sit'' command immediately
		3	obeys the ''stay'' command immediately
		4	seems to attend / listen closely to everything you say or do
		5[a]	is slow to respond to correction or punishment (''thick-skinned'')
		6[a]	is slow to learn new tricks or tasks
		7[a]	is easily distracted by interesting sights, sounds, or smells
		8	will retrieve (or attempt to retrieve) sticks, balls, or objects
Aggression	Dog acts aggressively	9	when verbally corrected or punished (scolded, shouted at, etc) by you or a household member
		10[b]	when approached directly by an unfamiliar adult while being walked / exercised on a leash
		11	when approached directly by an unfamiliar child while being walked / exercised on a leash
		12	toward unfamiliar persons approaching the dog while s/he is in your car (at a parking lot for example)
		13	when toys, bones or other objects are taken away by a household member
		14	when bathed or groomed by a household member
		15	when an unfamiliar person approaches you or another member of your family at home
		16	when unfamiliar persons approach you or another member of your family away from your home
		17	when approached directly by a household member while s/he is eating
		18	when mailmen or other delivery workers approach your home
		19	when his/her food is taken away by a household member
		20	when strangers walk past your home while your dog is in the yard
		21[c]	when an unfamiliar person tries to touch or pet the dog
		22	when joggers or cyclists pass your home while your dog is in the yard
		23	when approached directly by an unfamiliar male dog while being walked or exercised on a leash
		24	when approached directly by an unfamiliar female dog while being walked or exercised on a leash
		25	when stared at directly by a member of the household
		26	toward unfamiliar dogs visiting your home
		27	toward cats or other animals entering your yard
		28	toward unfamiliar persons visiting your home
		29[c]	when barked, growled or lunged at by another (unfamiliar) dog
		30	when stepped over by a member of the household
		31	when you or a household member retrieves food or objects stolen by the dog
		32[c]	towards another (familiar) dog in your household
		33[c]	when approached at a favorite resting / sleeping place by another (familiar) household dog
		34[c]	when approached while eating by another (familiar) household dog
		35[c]	when approached while playing with / chewing a favorite toy, bone, object, etc., by another (familiar) household dog
Fear and anxiety	Dog acts anxious or fearful	36[b]	when approached directly by an unfamiliar adult while away from your home
		37	when approached directly by an unfamiliar child while away from your home
		38	in response to sudden or loud noises (e.g. vacuum cleaner, car backfire, road drills, objects being dropped, etc.)
		39	when unfamiliar persons visit your home
		40[c]	when an unfamiliar person tries to touch or pet the dog
		41	in heavy traffic
		42	in response to strange or unfamiliar objects on or near the sidewalk (e.g. plastic trash bags, leaves, litter, flags flapping, etc.)
		43	when examined or treated by a veterinarian
		44	during thunderstorms
		45	when approached directly by an unfamiliar dog of the same or larger size

Appendix table: continued

Category		CBARQ item	
		46	when approached directly by an unfamiliar dog of a smaller size
		47	when first exposed to unfamiliar situations (e.g. first car trip, first time in elevator, first visit toveterinarian, etc.)
		48	in response to wind or wind-blown objects
		49	when having claws clipped by a household member
		50	when groomed or bathed by a household member
		51[c]	when having his/her feet toweled by a member of the household
		52[c]	when unfamiliar dogs visit your home
		53[c]	when barked, growled or lunged at by another unfamiliar dog
Separation-related behavior	When left or about to be left on its own, the dog displays	54	shaking, shivering or trembling
		55	excessive salivation
		56	restlessness/agitation/pacing
		57	whining
		58	barking
		59	howling
		60	chewing/scratching at doors, floor, windows, curtains, etc
		61	loss of appetite
Excitability	Dog overreacts or is excitable	62	when you or other members of the household come home after a brief absence
		63	when playing with you or other members of your household
		64	when doorbell rings
		65	just before being taken for a walk
		66	just before being taken on a car trip
		67	when visitors arrive at your home
Attachment and attention seeking	Dog	68	displays a strong attachment for one particular member of the household
		69	tends to follow you (or other members of household) about the house, from room to room
		70	tends to sit close to, or in contact with, you (or others) when you are sitting down
		71	tends to nudge, nuzzle, or paw you (or others) for attention when you are sitting down
		72	becomes agitated (whines, jumps up, tries to intervene) when you (or others) show affection for another person
		73	becomes agitated (whines, jumps up, tries to intervene) when you (or others) show affection for another dog or animal
Miscellaneous	Dog chases	74	cats (given the chance)
		75	birds (given the chance)
		76	other animals (e.g. rabbits) (given the chance)

[a]Scores on this item were reversed, i.e. never = 4, seldom = 3, etc

[b]Two items in the PennBARQ were fused to create this item. The PennBARQ is an earlier version of the CBARQ (Hsu and Serpell, 2003)

[c]Item was not present in the PennBARQ (Hsu and Serpell 2003)

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