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A Quick Assessment Tool for Human-Directed Aggression in Pet Dogs

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Many test series have been developed to assess dog temperament and aggressive behavior, but most of them have been criticized for their relatively low predictive validity or being too long, stressful, and/or problematic to carry out. We aimed to develop a short and effective series of tests that corresponds with (a) the dog's bite history, and (b) owner evaluation of the dog's aggressive tendencies. Seventy-three pet dogs were divided into three groups by their biting history; non-biter, bit once, and multiple biter. All dogs were exposed to a short test series modeling five real-life situations: friendly greeting, take away bone, threatening approach, tug-of-war, and roll over. We found strong correlations between the in-test behavior and owner reports of dogs' aggressive tendencies towards strangers; however, the test results did not mirror the reported owner-directed aggressive tendencies. Three test situations (friendly greeting, take-away bone, threatening approach) proved to be effective in evoking specific behavioral differences according to dog biting history. Non-biters differed from biters, and there were also specific differences related to aggression and fear between the two biter groups. When a subsample of dogs was retested, the test revealed consistent results over time. We suggest that our test is adequate for a quick, general assessment of human-directed aggression in dogs, particularly to evaluate their tendency for aggressive behaviors towards strangers. Identifying important behavioral indicators of aggressive tendencies, this test can serve as a useful tool to study the genetic or neural correlates of human-directed aggression in dogs. Aggr. Behav. 9999:XX–XX, 2013. © 2013 Wiley Periodicals, Inc.

Keywords: pet dogs; human directed aggression; predictive behavioral test

INTRODUCTION

Aggression is a complex behavior regulated by different sets of genetic, neurochemical, and hormonal regulators. Many of the intrinsic factors, such as neurotransmitters, hormones, pheromones, sex, and individual anatomical differences have been studied in a range of species. Animal research has focused mostly on natural forms of aggressiveness; in contrast human research is interested mainly in abnormal manifestations of aggression that are conceptualized as psychopathologies (Haller, 2013). The literature concerning brain circuitry and neuromodulators involved in manifestations of aggressive behavior is continuously growing, while behavioral investigations use only a limited set of experimental approaches and involve a limited set of species only (mainly mice and rats). Although such laboratory models are important, there is a need for greater validity in aggression research by including a wide range of behavioral phenotypes and species.

The dog has been suggested as a suitable model species for several forms of human social behavior (Topál et al., 2009), especially for human psychiatric conditions (Overall, 2000). However, as is often the case with human research (Freimer & Sabatti, 2003), while the genetic and physiological mechanisms of aggression are fairly well studied (Nelson & Trainor, 2007), the precise description of dogs' aggressive behavior is absent, and the selection of appropriate behavioral tests is a matter of debate (Taylor & Mills, 2006). In order to carry out a complex analysis on dog aggression, it is necessary to have a precise description at the behavioral level. Here

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we present a quick and easy-to-perform behavioral assessment for human-directed aggression in dogs.

Over the last decade, a number of tests have been developed to assess dog temperament, including aggressive behavior (Diederich & Giffroy, 2006; Mornement, Coleman, Toukhsati, & Bennett, 2010). Most of these behavioral tests have come from the applied field and are particularly concerned with the selection of shelter dogs for reintroduction to society (Ledger & Baxter, 1997; Poulsen, Lisle, & Phillips, 2010; van der Borg, Netto, & Planta, 1991), dogs for service work (Weiss & Greenberg, 1997), or for sport or breeding purposes (Netto & Planta, 1997; Wilsson & Sundgren, 1997). Recently, these topics have received more comprehensive attention from both the applied field (Jones & Gosling, 2005; Overall, Hamilton, & Chang, 2006; Taylor & Mills, 2006) and those studying human temperament and behavioral disorders (Gosling, 2001; Overall, 2000).

One of the most-cited aggression test series was developed by Netto and Planta (1997). This procedure consists of 43 subtests measuring dogs' intra-specific and inter-specific aggression in multiple contexts where the dog is startled, threatened, frightened, or otherwise stressed. The main advantage of this procedure is that it is suitable for detecting many different types of human- and dog-directed aggression. Planta (2001) shortened this test to the Sociable Acceptable Behavior test (SAB test) containing only 16 test elements. This shortened version was developed as an alternative which could easily be used by kennel clubs (De Meester et al., 2008; van den Berg et al., 2010).

Based on Netto and Planta's work, many test series have been used for different applied purposes (e.g., military dogs: Haverbeke et al., 2010; shelter dogs: Bollen & Horowitz, 2008; Orihel & Fraser, 2008; guide dogs: Batt, Batt, Baguley, & McGreevy, 2008; police dogs: Horváth, Igyártó, Magyar, & Miklósi, 2007). However, these procedures also have their limitations: for example, they contain many tests (e.g., Taylor & Mills, 2006), and the use of multiple frustrating and threatening situations within a short period of time is exhausting for the dogs. From an animal welfare viewpoint, it seems unnecessary to subject a dog to so many stressful situations, if a quick behavioral assessment can be used instead. By using fewer tests, the potential biases derived from order effects could also be reduced. Moreover it has been suggested that human- and dog-directed aggression are genetically different although partially related traits (Liinamo et al., 2007) making it plausible to study human-directed aggression separately.

In accordance with the above background, our study aimed to develop a robust and predictive test series that was as short as possible. We applied procedures taken from previously validated and/or widely used tests (e.g., Netto & Planta, 1997; Tóth, Gácsi, Topál, & Miklósi, 2008; van der Borg et al., 1991; Vas, Topál, Gácsi, Miklósi, & Csányi, 2005).

As a first step, we examined the characteristic behavioral differences between dogs with different biting history. We did not aim to map all possible aspects of aggressive behavior with our short test series and thus did not expect to find a 100% match between biting history and in-test behavior. Rather our goal was to develop a short and easy-to-use procedure that is sensitive to the aggressive tendencies of dogs (quantified by their biting history).

In addition to the behavioral analyses, we assessed correspondence between in-test behavior and the owners' opinions regarding the dogs' tendencies to show aggression towards humans. Netto and Planta (1997) used such a comparison for validating their test series, and they found that owners' reports reliably identified dogs with aggressive tendencies. As a second step, in order to measure the consistency of the dogs' behavior in our test series, we retested a subsample of dogs from all three groups and compared the two data sets.

METHOD

Subjects

A total of 73 adult (>1 year) pet dogs (24 different breeds and 20 mongrels, 35 males and 38 females, mean age 3.5 ± 0.27 years) participated in the test. The subjects were recruited from the database of volunteers of the Family Dog Project, Eötvös University, Budapest.

Based on owners' answers for our general questionnaire, first we chose dogs with a biting history towards humans, as such individuals seemed to be scarce in our data base. We found 47 subjects that, according to their files, had already bitten or snapped at a person at least once in their lives. These "biter" dogs were further divided into two subgroups, one containing dogs that had bitten only once during their life (OB group, $N = 22$), and the other containing dogs that had bitten on more than one occasion (MB group, $N = 25$). OB and MB groups did not differ regarding sex, age, and breed-group (based on the categorization of the largest international breeding organization, the Fédération Cynologique Internationale). We chose dogs from our list for the third, non-biter group so as to have a counterbalanced sample to that of the OB and MB groups in respect to FCI breed-groups, sex, and age. The individuals in the third group had no biting history (NB group, $N = 26$).

Procedure

Subjects were tested in a visually separated, unfamiliar, open-air area Figure 1. The test series consisted of five

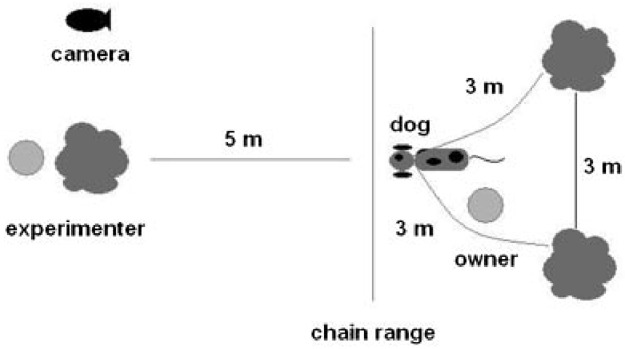

Fig. 1. The schematic figure of the test area.

tests in a fixed order. The reason for using a fixed order was twofold: the first test was expected to elicit less aggression than the others and our main aim was to characterize the overall aggressive response of the dogs instead of focusing on the differences between the individual tests. During tests 1–4, dogs were tethered to two trees (located about 3 m from each other), with two 3-m-long light chains in a V shape. This type of leashing prevents the dog from making semi-circular movements but allows it to move forward and backward, providing the possibility to avoid any stimuli during the test. The owner stood one meter away from the dog (see Fig. 1) without moving or speaking. In Test 5, the dog was put on a leash by the owner. The duration of each of the five tests was between 30 and 60 sec and the tests were carried out with only brief breaks (5–10 sec) necessary to prepare the subsequent procedure. Thus the whole test series took about 4 min per dog. Two unfamiliar female experimenters (E1 and E2) participated in the test series. Test 5 was performed by the owner. In Tests 1 and 2, E1 used an artificial hand. It was a very natural-looking model of a hand, made of plaster, and covered with a glove. The artificial hand could be operated by a stick covered with a sleeve to hide the hand of the test-person. The behavior of the human participants was determined and standardized according to several rules as follows.

Test 1—Friendly greeting: E1 approaches the dog in normal walking speed while speaking in a friendly manner to the dog and maintaining eye contact with it. She stops at 1 m from the dog. Then, she calls the dog by its name, steps closer if the dog approaches her without showing any sign of aggression, and strokes it gently on the head with the artificial hand. E1 continues repeating the dogs' name for 30 sec even if it shows aggression or avoids her, but she never goes closer than the chain range.

Test 2—Take away bone: For this test we use a bone attached to a string. E1 gives the bone to the dog to chew it while she holds the end of the string. The bone is always positioned a few centimeters inside the chain range, so that the dog can choose either to approach the experimenter and the bone or to avoid them. If the dog is motivated to chew the bone, then after 5 sec the experimenter strokes the dog's head with the artificial hand while talking to it quietly (5 sec); then she reaches towards the bone, puts the hand on the bone and says "Give it to me!" then without saying anything holds the artificial hand on the bone (5 sec); finally, she takes away the bone from the dog by pulling the rope with her other hand while the artificial hand remains on the bone pretending that she is pulling the bone with it. The test is terminated if the dog (a) tries to attack E1, (b) allows her to take the bone away, or (c) is not motivated to chew the bone.

Test 3—Threatening approach: E2 approaches the dog slowly, slightly leaning ahead, and staring into the dog's eyes (for detailed description, see Vas et al., 2005). The test ends when the experimenter reaches the chain range or when the dog reacts with aggression (growing, snarling, snapping) or avoidance (moving away from the experimenter).

Test 4—Tug-of-war: E1 tries to make the dog play tug-of-war using a 40 cm long rough fabric rag. If the dog cannot be motivated within 1 min, the test is terminated. With motivated dogs, E1 plays tug of war intensely but not aggressively. After a 20-sec-long play-session, E1 asks for the rag and takes it away by pulling (if it is not possible, then the owner takes the rag away from the dog).

Test 5—Roll over: Preceding the test the owner puts the dog on leash and puts a muzzle on it as he/she normally does before walks. The owner gently makes the dog lay on its back (so that the dogs' legs do not touch the ground), and attempts to keep the dog in this position for 1 min in total. The owner is instructed not to force the dog physically to lay on its back, but (s)he is allowed to hold it gently even if the dog tries to stand up.

All tests were video-recorded by the non-tester experimenter for later analysis.

After the tests, the owners were asked how often their dogs behave aggressively towards strangers (1–5 score) and towards the owner/family members (1–5 score).

Repeated Testing

Nineteen dogs from the three groups (NB: $N = 7$; OB: $N = 5$; MB: $N = 7$) were retested in the same test series (same procedure, test place, and experimenters) to examine behavioral consistency. These tests were conducted approximately 1 year after the first tests (mean period 12.9 ± 3.9 months).

Data Analysis

Variables. We selected and defined the relevant variables based on the findings from an earlier pilot study on 16 dogs. Table I shows the variables we coded in each of the tests.

In addition to aggressive responses, fear-related behavior was also analyzed because we assumed that behavior evoked by fear or frustration often leads to human-directed aggression in pet dogs. Inter-observer agreements for all variables were assessed by means of parallel coding of 15 dogs' tests randomly chosen from the three groups. High values for agreement between the two observers were found in all cases (Kappa coefficients are: 1 for aggression and fear, .84 for barking, and .87 for latency of roll over).

Statistical Analyses

We used non-parametric statistical methods to compare the behavior of the three groups. The Kruskal–Wallis test was used in the case of latency to roll over and aggression (except for the Test 4 where Fisher's exact test was used as no subject received an aggression score higher than 1). When differences between the three groups were significant, we applied the Mann–Whitney *U*-test for pair-wise comparisons. Chi-square test of independence was used in the case of fear and barking. When differences between the three groups were significant, we compared the size of the standardized residuals (Z) to alpha of .05 (i.e., ± 1.96). In case of very rare acts of behavior (aggression in friendly greeting and roll over) statistical analysis was not applied, and only the raw data are presented. To reveal more complex associations, in the threatening-approach test we also compared the relevant behavioral combinations (only fear; fear and aggression; only aggression; none) between the three groups with a Chi-square test. Furthermore, we used barking as a grouping variable to further analyze the relationship between aggression and fear (Mann–Whitney *U*-test).

To find correlations between owner reports and aggression shown during our test series, the Kendall test with Benjamini correction was applied. To assess the consistency of dogs' behavior across the first and repeated test series we used the Wilcoxon signed-rank test. Specificity and sensitivity measures were calculated for the test series and for each separate test based on data from NB and MB dogs. Specificity was defined as the number of true negatives (number of NB dogs that did not show aggression)/number of negatives (number of NB and MB dogs that did not show aggression), and sensitivity was defined as the number of true positives (number of MB dogs that showed aggression)/number of positives (number of NB and MB dogs that showed aggression).

This study was performed in accordance with the regulations of the University Institutional Animal Care and Use Committee (Hungary).

RESULTS

Friendly Greeting

Dogs in the NB group showed no aggression during this test. Only two dogs in the OB group and one in the MB group growled, and another two subjects from the MB group attacked the friendly approaching E1. The specificity of this test was 1 and the sensitivity was 0.12. Dogs, which behaved aggressively during friendly greeting test, also showed aggression in most of the other tests. There was a significant difference between the groups in fear responses ($\chi^2_{(2)} = 7.26$; $P = .02$). To determine which group or groups produced the

TABLE I. List and Definition of Behavior Variables Used in the Study

Test	Variable	Type of Variable	Definition of the Variable
Friendly greeting	Fear	0/1	Any of the following behaviors: tail holding/wagging between the legs, dipped head, tense posture, lay on back
	Aggression[a]	Score	0: no aggression; 1: growling; 2: snarling; 3: snapping with/without attacking; 4: biting
Take away bone	Aggression[a]	Score	0: no aggression; 1: growling; 2: snarling; 3: snapping with/without attacking; 4: biting
Threatening approach	Fear	0/1	Any of the following behaviors: tail holding/wagging between the legs, dipped head, tense posture, lay on back
	Barking	0/1	0: no barking; 1: barking
	Aggression[a]	Score	0: no aggression; 1: growling; 2: snarling; 3: snapping with/without attacking
Tug-of-war	Aggression[a]	Score	0: no aggression; 1: growling; 2: snarling; 3: snapping with/without attacking; 4: biting
Make the dog roll over	Latency of roll over	Latency	Time needed until the dog is first in the required position for at least 3 s
	Aggression[a]	Score	0: no aggression; 1: growling; 2: snarling; 3: snapping with/without attacking; 4: biting

[a]Score 0 = no aggression (none of the following behaviors); Score 1 = growling (acoustic threats; low buzzing sound); Score 2 = snarling (the dog pulls up its upper lip, so that its teeth are visible); Score 3 = snapping with or without acoustic and visual threats with incomplete approach (the obvious aim of the biting, an open muzzled movement towards the artificial hand or arm, without the total contact with it); Score 4 = biting with or without acoustic and visual threats (the artificial hand/arm totally gets into the jaws of the dog)—following Netto and Planta (1997). Barking, staring, and the rigid posture without snarling or growling were not noted as aggressive behavior elements (following Christensen et al., 2007).

statistically significant difference, we used the standardized residuals as indicators. Of the OB dogs 45% showed some fear response, which was higher than expected by independent distribution ($Z = 2.0$), meaning that fear related behaviors were over-represented in the OB group, compared to the expected frequency (NB: 12%; MB: 20%).

Take Away Bone

The motivation of the dogs in the different groups was fairly similar: only two dogs from the entire subject pool did not have physical contact with the bone. There was a significant difference in aggression between the three groups ($\chi^2_{(2)} = 8.49$; $P = .01$) as shown in Figure 2. MB dogs showed more aggression than both NB ($U = 226$; $P = .03$) and OB ($U = 175$; $P = .01$) dogs, while the latter two groups did not differ from each other ($U = 279$; $P = .83$). The specificity of this test was 0.81 and the sensitivity was 0.48.

Threatening Approach

The three groups differed in their aggression towards a threatening stranger ($\chi^2_{(2)} = 13.89$; $P < .001$) as shown in Figure 3. Both OB ($U = 163$; $P = .001$) and MB ($U = 176$; $P < .001$) dogs showed more aggression than NB dogs, while there was no difference between the two groups with reported biting history ($U = 255$ $P = .64$). The specificity of this test was 0.92 and the sensitivity was 0.56.

A difference was also found in the proportion of dogs showing fear between the three groups ($\chi^2_{(2)} = 11.84$; $P = .003$) as shown in Figure 4. Of the OB dogs 73% showed fear in this test, which was higher than expected by independent distribution ($Z = 2.9$), while only 23% of the NB dogs showed fear, which was below expectations ($Z = -3.0$). The fear responses in MB dogs (48%) did not differ from the expected ratio.

Investigating the associations of agonistic responses, we analyzed the combination of aggression and fear-related behavior of the individuals, comparing the proportion of subjects that showed only aggression (any type), both fear and aggression; only fear, or none of these. We found different reaction patterns between the three groups ($\chi^2_{(6)} = 26.56$; $P < .001$) as shown in Figure 5.

Dogs with different biting history also differed in their barking responses ($\chi^2_{(2)} = 8.41$; $P = .015$). Barking was

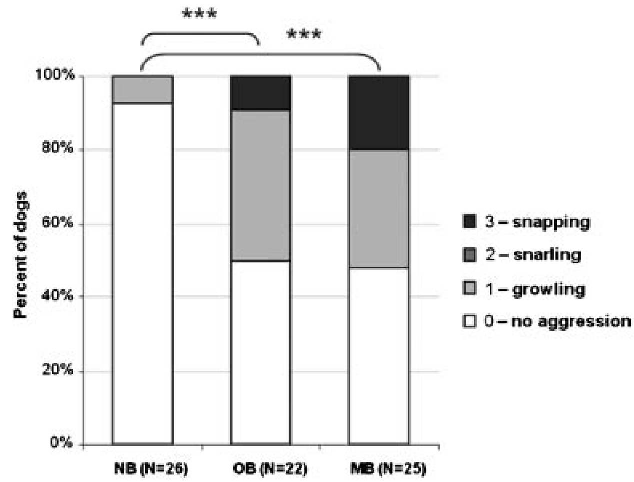

Fig. 3. Distribution of aggression scores in threatening approach test. Asterisks indicate significant differences (*$P < .001$). Score 4 is not presented, because biting was not possible due to safety reasons.**

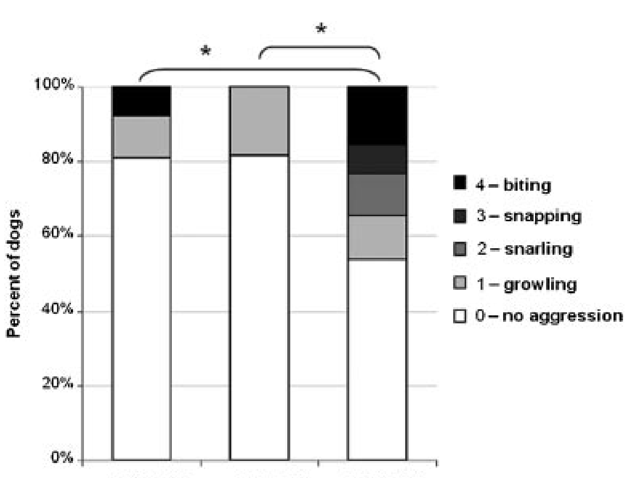

Fig. 2. Distribution of aggression scores in the take away bone test. Asterisks indicate significant differences between groups (*$P < .05$).

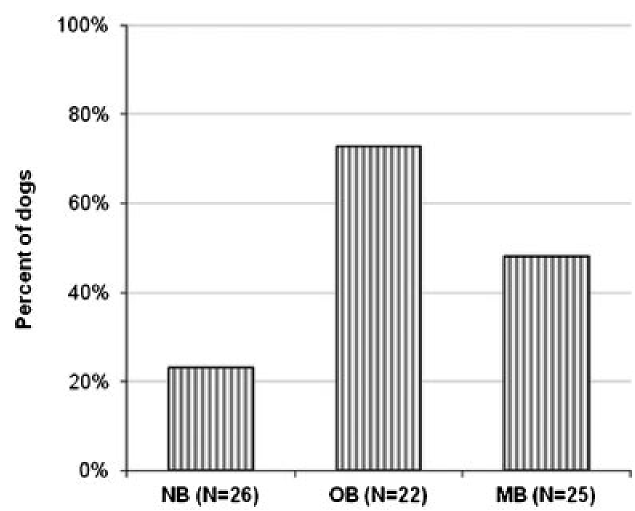

Fig. 4. Fear related behaviors in the threatening approach test. Distribution of dogs that showed fear related behaviors were different ($P = .003$) in the three groups. More OB dogs and less NB dogs showed fear than expected by independent distribution.

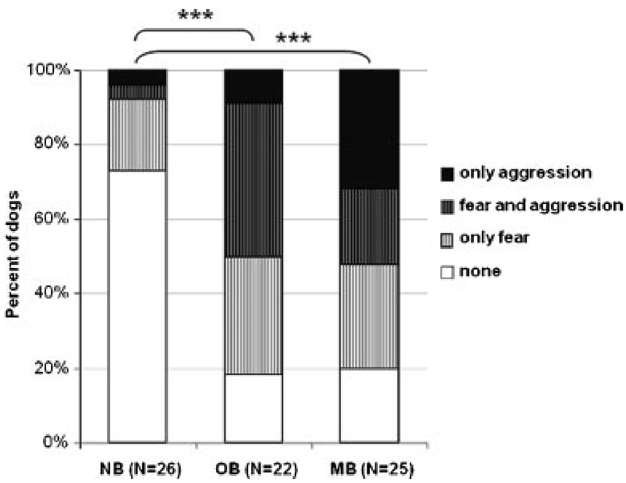

Fig. 5. Distribution of the combined scores of fear and aggression in the threatening approach test. Asterisks indicate significant differences between groups (*$P<.001$).**

less frequent in NB dogs than expected by independent distribution ($Z=-2.9$). To investigate the relationship between barking and agonistic behavior, we applied barking as a grouping variable and pooled the three groups together as one sample. Comparing the proportion of subjects that showed only aggression, (any type) both fear and aggression, only fear, or none of these, we found that the distribution of these responses was different in dogs depending on whether they barked or not during the test ($\chi^2_{(3)}=30.881$; $P<.001$). Barking was associated with fear, and both fear-related and non-fear-related aggression, as shown in Figure 6.

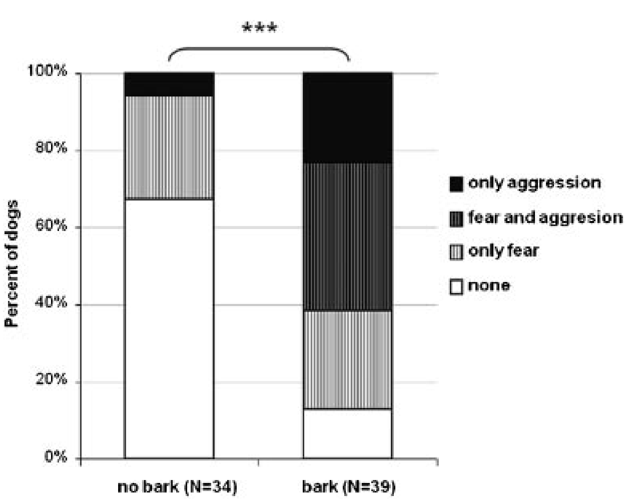

Fig. 6. Distribution of the combined scores of fear and aggression of all subjects in the threatening approach test using barking as a grouping variable. Asterisks indicate significant difference (*$P<.001$).**

Tug-of-War

The motivation of the dogs in the different groups was fairly similar: 54% of NB, 43% of OB, and 64% of MB dogs made physical contact with the rag. All together only ten dogs (NB: 2; OB: 2; MB: 6) showed aggression (all growled) during this test, and no difference was found between the groups (Fisher exact; $P=.24$). The specificity of this test was 0.92 and the sensitivity was 0.24.

Roll Over

The three groups did not differ in the latency of the first successful attempt to get the dog to lay on its back ($\chi^2_{(2)}=2.86$; $P=.24$). Only four dogs showed any form of aggression towards the owner during this test (NB: 2 growled; OB: 0; MB: 2 snapped). The specificity of this test was 0.92 and the sensitivity was 0.08.

Questions Asked From the Owner About the Dog's Behavior

We found a significant correlation between owner-reported tendency for stranger directed aggression and the occurrence of aggressive responses in the threatening approach test ($r=.33$; $P=.004$), in the tug-of-war test ($r=.34$; $P=.006$), and in the friendly greeting test ($r=.33$; $P=.007$). Correlations with aggression shown in the take away bone and in the roll over tests did not remain significant after the Benjamini correction. Owner-reported aggression towards the owner or other family members did not correlate with the aggressive behavior shown in any of our tests.

Specificity and Sensitivity of the Test Series

Taking together data of all five tests (Friendly greeting, Take away bone, Threatening approach, Tug-of-war, and Roll over) the specificity was 0.58 and the sensitivity was 0.80. When discarding the tests that did not differentiate between our three groups of subjects (Tug-of-war and Roll over), the specificity was 0.73 and the sensitivity was 0.76.

Reliability of the Test Series (Retesting)

To assess the consistency of the results across the first and repeated test series, we compared the behaviors observed in the two test occasions. No difference was found for any variables in any tests: friendly greeting (aggression: $Z=.00$, $P=1.00$; fear: $Z=.33$, $P=.74$), take away bone (aggression: $Z=1.00$, $P=.32$), threatening approach (aggression: $Z=1.22$, $P=.22$; fear: $Z=.45$, $P=.66$; barking: $Z=1.41$, $P=.16$), tug-of-war (aggression: $Z=.33$, $P=.74$) and roll over (aggression: $Z=.00$, $P=1.00$; latency of roll over: $Z=.16$, $P=.87$) tests.

DISCUSSION

The main objective of the present study was to develop a brief and welfare-compatible test series measuring human-directed aggression in pet dogs. To do so, we applied a relatively easy-to-perform test series composed of only five previously validated aggression tests. We compared the behavioral responses of dogs with different biting histories as reported by the owners. The results supported our major assumptions, as we found significant and specific differences between the groups. The specificity and sensitivity of the test series was also fairly good (>0.7). Higher specificity (>0.8) could be achieved by other test series using more tests (e.g., van der Borg et al., 1991, 2010), however in these cases a lower sensitivity (<0.4) was reported.

The friendly greeting test did not elicit any forms of aggressive behavior in most dogs. This could be due to the fact that the tests were carried out in an unfamiliar environment where dogs are usually more tolerant, conflict-avoiding, cautious and less self-confident than, for example, in their own territory (Diverio, Tami, & Barone, 2008). However, dogs that showed aggressive responses even during the friendly greeting behaved aggressively in most of the other tests as well. Thus this test can play an important role in identifying consistently aggressive dogs. Moreover, this test could serve as a good indicator of dogs' extreme fear of humans, which could lead to aggressive behavior in certain contexts.

It is a widely accepted notion among owners that no one should take food away from dogs. This idea is probably based on the fact that many otherwise friendly dogs guard their food not only from conspecifics but also from humans. Observations among wild (Mech, 1999) and captive (Mech, 1970) wolves show, however, that subordinate wolves protect pieces of food already in their possession from being taken even by dominant conspecifics. Mech (1999) claimed that there is an "ownership zone" around the mouth of each wolf, and regardless of the challenger's rank they try to retain the food already possessed. This might indicate that some aspects of food-guarding behavior are regulated in part independently of the social hierarchy. However, recently it was shown in a pack of free-ranging dogs that high-ranking individuals often stole food from other group members who commonly did not react (Bonanni, Natoli, Cafazzo, & Valsecchi, 2011). There are also breed differences in the food-guarding behavior of pet dogs, which are related to their different function, for example, retrieving hunted game to humans (Coppinger & Coppinger, 2001). These data indicate that during domestication, some feeding-related behavior has altered. As we expected, the take away bone test proved to be a situation that elicited aggression depending on the dogs' biting history towards humans, with multiple-biting dogs showing more aggression than both non-biters and occasional biters. This could be explained by several factors. Multiple-biting dogs might act aggressively in everyday life situations, whereas the aggressive action of occasional biters could happen in a rare, seriously threatening or frightening context, which was not necessarily mimicked in our test series.

In the threatening approach test, our results supported previous findings that human gazing combined with specific body posture and movements evoke fear and/or aggression in many pet dogs (Vas, Topál, Győri, & Miklósi, 2008). The occurrence and type of aggressive behavior shown during the threatening approach seemed to correspond with biting history. The efficiency of this test might be explained by the ambiguity of the human's intentions, which could elicit some form of aggression from both fearful/frustrated and assertive dogs.

Our results supported previous findings that fear plays a crucial role as an aggression trigger in pet dogs in some contexts. Interestingly, in our test, fear seemed to most affect the behavior of dogs that bit once prior to the test. Pageat (2004) claimed that fearful young dogs are at a greater risk of developing aggressive behavior later in life, and Guy et al. (2001) reported that biting dogs had significantly higher fear scores and a more pronounced tendency to be afraid of stimuli such as children or strangers. Furthermore, a significant association among fear/anxiety and aggression-related problems has been reported by other authors (Landsberg, Hunthausen, & Ackerman, 2003; O'Sullivan, Jones, O'Sullivan, & Hanlon, 2008). As in humans, dogs' fear responses within social situations are often learned (O'Farrell, 1992). In cities where most dog−human interactions are constrained by the leash, pet dogs often have no chance to choose flight or fight. If a dog can avoid a frightening/frustrating situation by showing aggressive signals, not much experience might be needed to learn the efficiency of this strategy when coping with social conflicts. Interestingly, in this respect, the fear responses of dogs reported to bite more than once fell between the other two groups. We can assume that fear-related aggression problems are most typical in the case of dogs that have no tendency to bite, but in rare cases, failing all else, they will bite. Dogs reported to bite only once showed most fear also in the friendly greeting test, supporting the view that this group was mainly composed of dogs prone to have fear-related aggression problems, but fear also seems to contribute to aggressive responses for some multiple biters. This indicates that when evaluating dog aggression, we need to consider fearfulness as an important factor to measure, because in some contexts fear may also lead to aggressive behavior even in the case of otherwise friendly dogs.

Our results did not support arguments for the predictive value of two test types widely used by dog experts, tug-of-war and roll over. Both are thought to be related to dominance aggression in dogs. The "dominance enhancement theory" suggests that uncontrolled tug-of-war games between the dog and a human partner lead to an increase in dominance dimensions of a dog's relationship with its play partner (Appleby, 1997; Rogerson, 1992). Moreover, it was suggested that winning tug-of-war games by the dog could present a direct dominance challenge by enhancing the dogs' perception of its status in the human-dog pack (O'Sullivan et al., 2008). Other studies claimed that playing tug-of-war games was associated with biting, and with having a history of aggressive behavior (Guy et al., 2001; O'Sullivan et al., 2008). In contrast, one could assume that a dog's competitiveness might determine whether it would prefer to play tug-of-war or not (Tóth et al., 2008). In other studies, no direct link was found between commonly played competitive games and dogs' aggression, or the dominance relationship between a dog and its human partner (Podberscek & Serpell, 1997; Rooney, 1999; Rooney & Bradshaw, 2002). In our experiment, the tug-of-war test did not differentiate among the three groups, as we did not observe marked aggressive responses in any of the groups. It cannot be excluded, however, that this could be explained by motivational aspects (i.e., dogs were less motivated to guard the rag than the bone). Anyway, the tug-of-war test did not successfully assess possession-related aggressive behavior in pet dogs: for comparison see dog versus wolf responses in a fairly similar context (Gácsi, Vas, Topál, & Miklósi, 2013). On the other hand, dogs' behavior in the tug-of-war test might be more partner-specific (i.e., dependent on the experiences of a certain individual).

A greater risk of showing aggression towards a familiar person was found in dogs whose owners used aversive training techniques, physical and/or verbal punishment (Herron, Shofer, & Reisner, 2009; O'Sullivan et al., 2008; Roll & Unshelm, 1997). It has been suggested that rolling a dog over as a punishment, a method derived from the superficial observation and false interpretation of passive submission in subordinate wolves, is associated with higher aggression and excitability scores (Arhant, Bartels, Bubna-Littitz, & Troxler, 2010). However, "alpha rolling" (roll over) is still widely used in many dog-training practices for establishing the owners' leadership, though the effectiveness and the biological relevance of this procedure are highly debatable. We hypothesized that rolling a dog over and maintaining the dog in that position in an unfamiliar place implied that there was a trustful relationship between the dog and its owner, otherwise this act might trigger frustration-related aggression (van der Borg et al., 1991). In our experiment this test not only failed to induce aggression, but even the struggling behavior of the dogs was not associated with their biting history.

Recent research has revealed that barking in the dog has evolved and is used for novel functions (Pongrácz, Molnár, & Miklósi, 2010). This suggests that novel forms of barking gained a functional significance in dog–human communication, and various forms of barking might be specific human-directed forms of acoustic communication. Some studies refer to barking as the indicator of aggressive inner state (Horváth et al., 2007; Hsu & Sun, 2010; Netto & Planta, 1997; Tami & Gallagher, 2009; van den Berg et al., 2010) while others evaluate it more cautiously (Christensen, Scarlett, Campagna, & Houpt, 2007; van der Borg et al., 1991). It is widely accepted that dogs bark in different situations and this vocalization can be related to both aggressive and non-aggressive (attention seeking, despair, playful, happy, and fearful) inner states (Christensen et al., 2007; Pongrácz, Molnár, & Miklósi, 2006; Pongrácz et al., 2010). Although, for example, dogs that bark as part of chasing behavior are considered less dangerous than those who do not bark (Overall, 1997), our results suggest a positive association between barking and aggressive behavior, indicating that the type and function of dog vocalization are context-specific. It is important to note that fear-related behavior was also accompanied by barking. Thus our findings suggest that barking may reflect different emotional states as well as ambiguity, and should be interpreted carefully. Acoustically more detailed analyses of barking could add important data to aggression-related studies (Molnár, Pongrácz, Dóka, & Miklósi, 2006).

For an observed behavior (e.g., growling or bite) to be regarded as a characteristic trait, it must be found to be consistent and show reliable stability over time (Vas et al., 2005). Thus, to establish the relevance of the present procedure, we repeated the test series with the same subjects a year later. Importantly, the relevant behavior proved consistent over time. Our findings are in accordance with some earlier results (Netto & Planta, 1997; Vas et al., 2008), but contradictory to others who concluded that aggression-related behavior is not consistent (Goddard & Beilharz, 1985; Svartberg et al., 2005) due to uncontrolled changes in the social environment. In addition to the differences in the type of tests and the procedure used, this discrepancy might be explained by the type of aggression studied. For example, territorial aggression and intra-specific aggression can be connected to very specific contexts. Such aggressive tendencies might not be reliably exhibited during temperament testing (Christensen et al., 2007).

While some earlier studies claimed that aggressiveness measured in a behavioral test shows low association with answers generated from owner questionnaires (Svartberg et al., 2005), we found a correlation between dogs' in-test behavior and owner-reported aggressive tendencies towards strangers. However, owners' reports of dogs' aggressive tendencies towards themselves and/or a familiar people did not correlate with dog in-test behavior. There could be a number of explanations for this result. First, the only test that required the owner's active participation (roll over), and could have measured owner-directed aggression, failed to induce aggression. Thus the inclusion of further tests (e.g., the owner carrying out a Take away bone test) may be necessary in order to measure owner-directed aggression. Second, the owners might be less likely to be genuine when they are asked about their dogs' aggressive tendencies towards themselves. Third, it is also possible that attacks towards familiar humans occur mainly in a familiar environment (e.g., own territory), and one cannot separate these components in a test carried out in an unfamiliar place. Predicting aggression towards the owner and/or family members would be important from an applied point of view as this is one of the most common complaints (Christensen et al., 2007). A further issue to investigate is whether owner-directed aggression can be predicted without the active participation of the owner during the test; this might be necessary in cases when the dogs are tested without their owner, for example, in shelters.

In comparison to earlier experiments, our procedure had several advantages both from a practical and from an animal welfare point of view. Including only a few tests decreased the possibility for bias due to order effect, and also gave less chance for habituation or sensitization. Moreover, although studies assessing welfare aspects of behavioral tests using physiological measures (e.g., cortisol level, heart rate) are lacking, it is plausible to assume that using fewer tests exposes dogs to less stress. Our procedure is safe, both for dogs and experimenters. It can also be used on extremely dangerous dogs, without the participation of the owners as it was already applied by the authors on dogs that had killed or seriously injured humans, in Hungary (still unpublished data).

While there are notable advantages of our test design, there are also some limitations. Although we attempted to design different situations that prompt aggression, for practical and ethical reasons, we did not test dogs in all possible aggression-provoking contexts (e.g., pain-related aggression, territorial aggression). Additionally, the selection of dogs that participated in this study cannot be considered as representative of the general population. The sample was biased towards relatively well-socialized dogs in the sense that most of them had been regularly walked or attending dog-training schools. We also need to consider that dogs' biting history can be influenced not only by the aggressive tendencies of the dogs, but also by the owner's behavior and providence (e.g., he/she keeps the dog under close control, muzzles the dog, and avoids conflict situations). Thus, even individuals with no biting history might have aggressive tendencies (Planta, 2001). In our study, dogs that bit once provided the most ambiguous group, showing fear and aggression-related responses in parallel. For a complete analysis, it would be important to know what additional factors caused that one bite and why the dog did not bite again.

Finally, an important lesson of our study was that the tug-of-war and rolling-over tests can be abandoned and the procedure should include only the three effective tests; friendly greeting, take away bone, and threatening approach. These tests seem to allow for an approximate, quick, and general assessment of stranger-directed aggression in pet dogs. Alternatively, additional tests investigating the owner directed aggressive behavior might replace the two abandoned tests.

CONCLUSIONS

Besides revealing interesting associations between aggression and fear-related behavior, our short and focused test series proved to be an effective tool for differentiating groups of dogs with different biting histories. Therefore, we suggest using our three-phase procedure, including the friendly greeting, take away bone and threatening approach tests, for a quick assessment of a dogs' behavioral profile in relation to stranger-directed aggression.

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