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A possible basis for personality in dogs: Individual differences in affective predispositions

Kenth Svartberg *

Swedish University of Agricultural Sciences, Department of Anatomy, Physiology and Biochemistry, Box 7011, SE-750 07 Uppsala, Sweden

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ABSTRACT

Previously, dog personality traits that seem to correspond have been identified by the Dog Mentality Assessment (DMA) and the Behaviour and Personality Assessment in Dogs (BPH): Playfulness, Sociability, Curiosity/fearlessness (DMA) vs. Non-social fearfulness (BPH), Aggressiveness, and Boldness. The first aim was to study the relationship between these traits. Correlation analyses on data from 1078 dogs subjected to both assessments revealed moderate correlation for Aggressiveness ($r = 0.25$) and high correlations ($r = 0.47–0.59$) for the other four corresponding traits, which indicates that they reflect similar aspects of dog personality. Considerable correlations were found after up to four years between assessments, suggesting temporal stability over longer periods of time. The second aim was to analyse the data set from a core-affect point of view. Two major dimensions were identified using principal component analysis and multidimensional scaling analysis (MDS). The first dimension was correlated positively with object play, pro-social behaviour, and exploration, and negatively correlated with fear-related variables, whereas the second dimension had its highest correlations with variables related to aggressiveness. The MDS analysis suggested a circular arrangement of the assessment variables in two-dimensional space, implying that several aspects of the assessed behaviour were related to both dimensions. The correlation pattern for data from a questionnaire related to everyday behaviour was in line with the results and provided additional information about the character of the two-dimensional space. The two dimensions may, at a state level, be interpreted as valence and arousal, respectively, and seem to reflect core affect in dogs. At a trait level, the dimensions seem to represent boldness and impulsivity, respectively. The second dimension may also indicate a coping strategy in challenging situations. From this point of view, the assessed behaviour may serve as the observable indicator for both stable personality and temporary affective states. Thus, the personality traits may, at least partly, be defined as individual differences in affective predispositions. From the current results, an affect-based model may be elaborated in which profiles of individual dogs or groups of dogs can be identified by the DMA and the BPH. There are several possible applications, for example in the identification of affect-related markers for problem-causing behaviour, welfare, and working performance in dogs. Due to the similarities with affect- and personality-related models used in humans, the two-dimensional space may be useful in comparative studies in areas such as genetics, well-being, mental health, and personality.

1. Introduction

While we cannot know how animals experience emotions, emotional life in animals has long been scientifically recognised (e.g., Darwin, 1872/, 1965; McDougall, 1918). This is due to an approach where emotions are considered multicomponent responses with observable and measurable components that may be used as indicators for emotional states (Kremer et al., 2020; Paul et al., 2020). In the recent

Abbreviations: AL, Assessment leader, who guides and instructs the handler during the assessment; BPH, Behaviour and Personality Assessment in Dogs; C-BARQ, Canine Behavioural Assessment and Research Questionnaire; CMA, Circumplex Model of Affect; D1, The first extracted component/dimension from the PCA/MDS; D2, The second extracted component/dimension from the PCA/MDS; DMA, Dog Mentality Assessment; FFM, Five-Factor Model of personality; MDS, Multidimensional scaling analysis; P, Phase, part of a subtest in the BPH; PCA, Principal Component Analysis; RV, Representative value; trait score, protocol item or questionnaire item that is used in the calculation of a trait score; S1–S7, Spreadsheet number in the supplementary Excel file; SKC, Swedish Kennel Club; ST, Subtest, part of the assessment; SWDA, Swedish Working Dog Association.

* Correspondence address: Voxome 102, SE-747 91 Alunda, Sweden.
E-mail address: kenth.svartberg@slu.se.

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decades, the study of emotion-related states in animals has developed notably due to progress in the study of animal physiology, cognition, and behaviour (e.g., Panksepp, 2011; Briefer, 2012; Cook et al., 2015; Descovich et al., 2017; Berridge, 2018; Crump et al., 2018; Lagisz et al., 2020; Siniscalchi et al., 2021). Today, the scientific study of animal emotions is a well-established scientific field, where the pursuit of finding valid indicators for subjective emotional experiences is central (De Waal, 2011; de Vere and Kuczaj, 2016; Kremer et al., 2020; Paul et al., 2020).

One view of emotions is as discrete entities, some of which are considered basic, with unique physiological and signalling features evident in both humans and animals (e.g., Tracy and Randles, 2011). Emotions may also be considered as cognitive constructions based on core affect, which is regarded as the basis of emotion (e.g., Barrett and Russell, 1999; Russell, 2003; Barrett and Bliss-Moreau, 2009). Core affect, as defined in the Circumplex Model of Affect (CMA), is an integral blend of valence and arousal, where valence is related to hedonic tone that can be seen as a pleasant/unpleasant emotional dimension, and arousal, or activation, refers to the degree of mobilisation or energy (Russell, 1980, 2003; Barrett and Russell, 1999; Barrett and Bliss-Moreau, 2009; Bliss-Moreau et al., 2019). Discrete emotions may be defined, at least partly, by the specific combination of valence and arousal, i.e., by the location in the core affective space. This view is the basis for a framework for the study of emotions in animals proposed by Mendl et al. (2010), which has been applied to several emotion-related issues and species (e.g., Burman et al., 2011; Briefer, 2012; Baciadonna and McElligott, 2015; Travain et al., 2016).

In humans, links between temporary affective states and enduring personality traits have been found, which indicate that certain personalities are predisposed to experience certain emotional states more often, more intensely and for a longer period, compared to other personalities (e.g., Larsen and Ketelaar, 1991; Matthews and Deary, 1998). Despite some indications of stable emotional predispositions in animals (e.g., Sheppard and Mills, 2002; Alexander et al., 2021), the aspect of individuals' different propensities for affective states has been largely overlooked in animal studies (de Vere and Kuczaj, 2016; Kremer et al., 2020). For this purpose, the Five-Factor Model of personality (FFM), which includes the dimensions Extraversion, Neuroticism, Agreeableness, Openness, and Conscientiousness (e.g., McCrae and John, 1992), can be a useful framework. Extraversion and Neuroticism are dimensions with clear emotional connection in humans and have been associated with a tendency toward positive and negative affective states, respectively (Costa and McCrae, 1980; Larsen and Ketelaar, 1991), but individual general tendencies in core affect have been linked to all personality dimensions within the FFM (e.g., Yik et al., 2001; 2002). The FFM has been applied to several animal species, among them dogs (Gosling and John, 1999; Gosling et al., 2003), and may be used as a bridge between species in the study of biologically rooted personality traits and emotional predispositions.

Two assessments that may be suitable for this purpose are the Dog Mentality Assessment (DMA) and the Behaviour and Personality Assessment in Dogs (BPH), used to identify individual behavioural differences in dogs. The DMA is organised by the Swedish Working Dog Association (SWDA) and, in its current form, has been used in breeding evaluation of working dogs since 1997 (Svartberg and Forkman, 2002). It includes 10 subtests assessing dog's reactions using rating scales with predefined steps. While the DMA was developed for working breeds, it became popular among owners and breeders of non-working dog breeds. Requests for a more general assessment from breeders as well as breed organisations of non-working breeds, especially companion-dog breeds, were responded to by the Swedish Kennel Club (SKC). This led to the development of the BPH, which was launched in 2012. Many of the subtests are similar to those of the DMA, with improvements regarding accessibility for dogs of different sizes, degree of standardisation and a more detailed assessment (Svartberg, 2021). Behavioural traits have been identified by the DMA, e.g., Sociability, Playfulness, Curiosity/fearlessness, and Aggressiveness, as well as the higher-order Boldness trait (Svartberg and Forkman, 2002). Since the traits have been found to be genetically influenced (Strandberg et al., 2005; Saetre et al., 2006; Arvelius et al., 2014), show stability over repeated assessments (Svartberg et al., 2005), and may be used in the prediction of working-dog performance (Svartberg, 2002) and everyday behaviour (Svartberg, 2005), they have been considered as dog personality traits. Similar traits have been detected by the BPH (Svartberg, 2021), which indicates that the two assessments may act on the same domains of dog personality.

Among the identified traits, the higher-order trait Boldness is of special interest. Boldness has been found to be positively correlated with play, exploration and a pro-social attitude, and negatively with avoidance and inhibition (Svartberg and Forkman, 2002; Svartberg, 2021). In FFM terms, Boldness has been interpreted as a dimension ranging from high Extraversion/low Neuroticism to low Extraversion/high Neuroticism (Svartberg and Forkman, 2002; Svartberg, 2021). Due to the association these FFM traits have with affect, Boldness may, on a state level, serve as a measure of overall valence during the assessment and indicate the dog's general tendency to experience pleasant and unpleasant feelings. A trait that may reflect activation/arousal in the DMA or the BPH has not yet been detected, even though an axis orthogonal to the Boldness dimension was identified through principal component analysis (PCA) by Svartberg (2005), which was correlated with Aggressiveness.

The aim with this study is two-fold. Firstly, the relationship between the apparently corresponding traits from the DMA and the BPH was studied to find out whether the assessments do act on the same domains of dog personality. Secondly, data from both assessments were analysed and interpreted from a core-affect point of view in search for behavioural indicators for affective states, based on Svartberg's (2005) finding of a possible two-dimensional personality-related space. For these aims, data from 1078 dogs assessed in both the DMA and the BPH were used. As a first step, the correlations between corresponding traits from the DMA and the BPH were analysed. Based on these, a principal component analysis (PCA) was performed, where two components were extracted to elucidate the overall relationship between the corresponding traits. PCA is suitable in simple structured data and when the aim is to extract discrete factors, whereas circumplex structures may be more parsimoniously represented by multidimensional scaling analysis (MDS) (Davison, 1985; Saucier, 1992). Therefore, to investigate whether any circumplex structure could be identified in the data set, a MDS was carried out on specific measures from the DMA and the BPH. In addition, data for 291 of the dogs from a questionnaire related to everyday behaviour were analysed in relationship to the two dimensions.

2. Methods

2.1. Sample description

The study was based on data from the database of the Swedish Kennel Club (SKC) and provided by the SKC. Therefore, animal care and use committee approval was not required. Dogs that fulfilled four criteria were included in the dataset: 1) assessed using both the DMA and the BPH, once per assessment type, 2) a maximum age of three years at the first assessment, 3) maximum four years between assessments, and 4) no missing values for the corresponding DMA and BPH traits (Sociability, Playfulness, Non-social fearfulness (BPH)/Curiosity/fearlessness (DMA), Aggressiveness, and Boldness). These criteria were met by a total of 1078 dogs including 579 females (53.7 %) and 499 males (46.3 %). One hundred and thirty-two breeds were represented, with one to 83 dogs per breed (see supplementary materials, S3). The age of the dogs when assessed in the DMA ranged from 366 to 1930 days (mean = 642 days), and the age when assessed in the BPH ranged from 367 to 2389 days (mean = 900 days). The time between the assessments ranged from two to 1456 days (mean = 438 days). For 671 dogs, the first

assessment was DMA, whereas 407 dogs were first assessed in the BPH. The data were collected using the DMA between August 2008 and November 2020 on 862 occasions at 171 assessment sites by 163 raters. In the BPH, the data were collected between March 2012 and December 2020 on 737 occasions at 50 assessment sites by 72 raters.

Data from an online questionnaire with items related to everyday behaviour were used in the analysis (Svartberg, 2021). The questionnaire data were collected between June 2012 and October 2020 in a joint project between the SKC and the Swedish University of Agricultural Sciences. Questionnaires on dogs with an age of 1–4 years when the questionnaire was received, and which were received within three years from both the DMA and the BPH, were used in the analyses. Questionnaires from a total of 291 dogs met these criteria (see supplementary materials, S3, for sex and breed distribution). The age of these dogs ranged from 365 to 1457 days (mean = 836 days) when the questionnaire received. The time between the DMA and the questionnaire ranged from 10 to 1080 days (mean = 377 days) with 99 questionnaires received prior to the DMA and 192 after. The time between the BPH and the questionnaire ranged from 0 to 1046 days (mean = 92 days). Two hundred and eight questionnaires were received prior to the BPH, and 83 on the same day as or after the BPH.

2.2. The assessments and behavioural measures

The DMA and the BPH are battery-type assessments with ten and eight subtests (ST), respectively. The equipment for the subtests was located along a pathway and subtests were carried out in the same order for each dog. The dog was accompanied by a handler, the owner, or a person familiar to the dog, who was instructed to remain quiet during the assessment. The handler was guided and instructed by an assessment leader (AL), who first met the dog in ST1 of each assessment. A rater made the behavioural assessments and additional figurants acted in some of the subtests. All persons involved in the test had been trained and certified by the SWDA (DMA) or the SKC (BPH). The assessments are described in detail in Svartberg and Forkman (2002) (DMA) and in Svartberg (2021) (BPH). Additional information in Swedish is found in SWDA (2021) for the DMA, and in SKC (2017a); b) for the BPH.

2.2.1. The DMA

Thirty-three behavioural rating scales are used in the DMA protocol (see supplementary materials, S1). The scales, which are pre-defined with a description for each step in the protocol, have five steps (1−5) according to the intensity of the reaction.

2.2.1.1. ST1: social contact. The AL greeted the handler and then the dog, whereafter the AL took the dog on a leash for a short walk (10 m.). The AL stopped and petted the dog at a distance from the handler. Back with the handler, the AL made physical contact with the dog. The dog's greeting reaction (1a), willingness to cooperate (1b), and reaction to physical handling (1c) were rated.

2.2.1.2. ST2: play 1. The handler invited the dog to play with a toy (a rag), which was thrown between the handler and the AL three times, whereafter the AL threw the toy away from the dog. This procedure was repeated. Thereafter, the AL initiated a game of tug-of-war with the dog. The dog's interest in playing (2a), grabbing behaviour (2b), and interest in playing tug-of-war (2c) were rated.

2.2.1.3. ST3: chase. A furry prey-like object was set in quick motion in a zig-zag pattern away from the dog. After the object was put into motion, the dog was free to run after it and grab it. The test was performed twice. The dog's interest in following (3a) and grabbing the object (3b) were rated.

2.2.1.4. ST4: passive situation. The dog and the handler were stationed for 3 min. The dog was leashed but free to move around the handler. The dog's activity level (4) during this period was rated.

2.2.1.5. ST5: distance play. A figurant wearing a cape with hood, positioned approx. 40 m. away, clapped his/her hands, moved towards the dog, and crouched. Thereafter the figurant unhooded and invited the dog to play with a toy (a rag), whereafter he/she ran to a hiding place. The dog was then released. If, and when, the dog approached the figurant, he/she invited the dog to play. The dog's interest in the figurant (5a), aggression (5b), exploration (5c), interest in playing tug-of-war (5d), and tendency to invite to play (5e) were rated.

2.2.1.6. ST6: sudden appearance. A human-like dummy (a boiler suit with arms extended horizontally) was suddenly pulled up in front of the dog while it was walked. The handler stopped and released the leash. After the dog had explored the dummy, the handler took the dog on a walk close to it four times. The dog's startle reaction (6a), aggression (6b), exploration (6c), and remaining avoidance and approach during the walk (6d and 6e) were rated.

2.2.1.7. ST7: metallic noise. A sudden metallic noise was produced by pulling a metal chain with large links over a sheet of corrugated metal when the handler and the leashed dog passed it. When the chain was pulled, the handler stopped, and released the leash. After the dog had explored the equipment, the handler took the dog for a walk close to it four times. The dog's startle reaction (7a), exploration (7b), and remaining avoidance and approach during the walk (7c and 7d) were rated.

2.2.1.8. ST8: ghosts. Two figurants draped in white sheets and white head covers with black-marked holes for eyes and mouth ('ghosts') slowly approached the dog. Initially, the ghosts were hidden at two places approx. 20 m. away at an angle of approx. 90° from the dog's position. Thereafter, the ghosts moved slowly in several short intermittent stages towards the dog until they stopped close to the dog/handler. The ghosts turned around whereafter the dog was released. The dog's aggression (8a), attention (8b), avoidance (8c), exploration (8d), and contact/greeting behaviour (8e) were rated.

2.2.1.9. ST9: play 2. This subtest was a repetition of the first play test, except for the tug-of-war part. The dog's interest in playing (9a) and grabbing behaviour (9b) were rated.

2.2.1.10. ST10: gunshots. Four starter gunshots were fired 20 m. away from the handler and the dog. The first two while the handler played with the dog, the subsequent two while the handler was passive. The dog's avoidance reaction (10) was rated.

Four of the narrow traits that have been detected by the DMA—Sociability, Playfulness, Curiosity/fearlessness, and Aggressiveness—as well as the higher-order trait Boldness were regarded as having counterparts among the BPH traits and used in the correlation analysis and in the PCA. The same representative values (RV) that had been used previously for the narrow traits (Svartberg, 2002, 2005; Svartberg et al., 2005; see supplementary materials, S5) were used in this study with one exception. Namely, attention towards ghosts was not used as an RV for Aggressiveness to balance the trait value against one aggression variable from each of the three subtests Distance play, Sudden appearance, and Ghosts. To calculate the Boldness trait value, the Sociability, Playfulness, and Curiosity/fearlessness values were used as RV in line with the calculation made by the SKC. The negative RV were reversed, whereafter all RV were standardised (subtracting the mean and dividing by the standard deviation) and the mean of the RV for each trait was calculated and used as the trait value. A maximum of 50 % missing RV for each trait was accepted. A total of 144 DMA protocol items were missing in the data set (0.40 %), with a mean of 0.13 per dog

(ranging from 0 to 11 per dog). If the handler refrains from exposing the dog to gunshots in the DMA, the avoidance reaction in S10 is scored as a five; all such scores were deleted from the dataset before the analyses.

2.2.2. The BPH

In the BPH protocol, 47 behavioural rating scales are used to describe the intensity, duration, latency, frequency, pace, or quality of the behavioural reaction. Each step on the scales, which range from three to eight, is pre-defined and has a written behavioural description in the protocol (see supplementary materials, S2). Most of the scales are used more than once, giving a total of up to 241 behavioural ratings in the protocol (see Svartberg, 2021). The subtests in the BPH are divided into one to three phases (P) per subtest.

2.2.2.1. ST1: unfamiliar person. The AL approached the handler and the dog and invited the dog to interact (P1). Thereafter, the AL invited the dog for a short walk with interaction (P2), whereafter the dog was physically touched (handled) by the AL in a standardised procedure (P3).

2.2.2.2. ST2: object play. The handler invited the dog to play with a toy familiar to the dog (brought by the handler) (P1). Thereafter, the handler invited the dog to play with a standardised toy (P2). The AL then invited the dog to play tug-of-war with the standardised toy (P3).

2.2.2.3. ST3: food interest. The dog was released and free to eat open tidbits and to try to reach hidden tidbits during 60 s.

2.2.2.4. ST4: visual surprise. A dummy was rapidly raised in front of the dog during a walk (P1). The dog was free to approach the dummy and initiate contact with it (P2). After contact with the dummy, the handler took the dog for a walk passing the dummy four times (P3).

2.2.2.5. ST5: metallic noise. A metal barrel with chains inside started to rotate (creating a rattling noise) in front of the dog during a walk (P1). The dog was free to approach the barrel and initiate contact with it (P2). After contact with the barrel, the handler took the dog for a walk passing the barrel four times (P3).

2.2.2.6. ST6: approaching person. An oddly dressed person slowly approached the dog (P1). When the person stopped and turned around in front of the dog, the dog was released and free to approach the person (P2).

2.2.2.7. ST7: unstable surface. The dog was encouraged by the handler to step up onto an unstable surface and pass back and forth over it (P1). The dog was encouraged by the handler to step up onto a second unstable surface and pass back and forth over it (P2).

2.2.2.8. ST8: gunshots. A shot from a starting gun was fired while the dog was walked by its handler (P1). A second shot was fired while the handler and the dog were standing still (P2).

Of the 41 BPH traits identified in a factor analysis procedure in Svartberg (2021), counterparts were found for five of the DMA traits: Sociability, Playfulness, Non-social fearfulness, Aggressiveness, and Boldness. These were used in the correlation analysis of corresponding traits and in the PCA. For the MDS analysis, traits from the 28th factor level in Svartberg (2021) were used. Based on the loadings > 0.4 from the factor analysis in that study, potential RV among the protocol items for each of these factors were suggested (due to a minor revision of the BPH, four items in S7 were dropped in 2018 and not used as potential RV). Using measures of internal consistency reliability from a sample with more than 24,000 assessed dogs as a guideline (not published), a set of suggested RV for each factor were put together, a total of 158 variables, and used in this study to calculate trait values (see supplementary materials, S7). A total of 1509 DMA protocol items were missing from the data set, representing 0.89 %, with a mean of 1.40 per dog (ranging from 0 to 23 per dog). To avoid erroneous missing value replacements, all scales were transformed to scales ranging from 0 to 7. This was done using the formula $Y = (B - A) * (x - a) / (b - a) + A$ (a = the minimum on the original scale, b = the maximum on the original scale, A = the minimum on the new scale, B = the maximum on the new scale, x = the dog's score on the original scale, Y = the dog's score on the new scale) (IBM, 2020). As a first step in the replacement of missing values, the mean of the RV for each trait was calculated. Thereafter, each missing value, given that maximum 50 % of the RV for the trait was missing, was replaced with the 0–7 scale step closest to the mean. The negative RV were reversed (since they are negatively correlated with the trait value), all RV were standardised, and the mean of the RV for each trait was calculated and used as the trait value.

2.2.3. The questionnaire

Information and a link to the questionnaire were posted on the SKC website (https://skk.se), and dog owners planning to take the BPH were encouraged to respond. In addition, information regarding the questionnaire was sent to owners of dogs registered for the assessment. The questionnaire included questions regarding the respondent and the identity of the dog, and 132 behaviour-related items, describing situations dogs might encounter in everyday life (see supplementary materials, S6). Most of them ($N = 82$) originate from a Swedish translation of the Canine Behavioural Assessment and Research Questionnaire (C-BARQ; Hsu and Serpell, 2003; Duffy and Serpell, 2012) with 17 added items used in Svartberg (2005). For appropriate validation of the BPH, additional 33 items were added in the online version, of which 12 were used in Svartberg (2021). The items were grouped in sections related to behavioural categories (training and obedience, aggression, fear and anxiety, separation-related behaviour, excitability, attachment or attention-seeking, play behaviour, social contact and miscellaneous), with a brief explanation of typical signs. The respondent was requested to describe the dog's typical behaviour in the recent past as objectively and neutrally as possible. For 71 of the items, the scale indicated the intensity of the behavioural expression, ranging from no sign of the behaviour (e.g., 'no visible signs of aggression') to intense expression (e.g., 'serious aggression: snaps, bites, or attempts to bite'), whereas for the remaining 61 items a rating scale was used to indicate the frequency of the behaviour ('never', 'seldom', 'sometimes', 'usually', or 'always'). The answers in the questionnaire were transformed to scales from 1 to 5 according to frequency or intensity, where 5 equalled the most frequent or strongest expression. Values for 21 subscales were calculated: 14 originating from the C-BARQ (attachment or attention-seeking behaviour, chasing, dog-directed aggression, dog-directed fear, dog rivalry, energy level, excitability, nonsocial fear, owner-directed aggression, separation-related behaviour, stranger-directed aggression, stranger-directed fear, touch sensitivity, and trainability), three from Svartberg (2005) (dog-directed interest, human-directed play interest, and stranger-directed interest), and four from Svartberg (2021) (exploration tendency, fear recovery latency, noise-related fear, and stairs/-surface fear) (see supplementary materials, S6). For the subscale values, the mean of the RV for each subscale was used in line with Duffy and Serpell (2012) and Svartberg (2005, 2021) provided that at least 50 % of the representative items was non-missing. Since aspects of everyday behaviour not represented by subscales could be of relevance, the item values in addition to the subscale values were used in the correlation analysis. A total of 1980 items were missing from the data set, representing 5.15 % (mean = 6.80 per dog, range = 0–120).

2.3. Statistical analysis

The internal consistency reliability of the aggregated traits and the questionnaire subscales was analysed by calculating Cronbach's alpha and the average inter-item correlations. Due to the appropriateness for

ordinal scales, which is used in all three assessment types, the analyses were based on polychoric correlations. For DMA Boldness, which is based on aggregated traits, the internal consistency measures were based on Pearson product-moment correlations, as the relationship between the corresponding DMA and BPH traits. Besides an analysis in the total sample, correlations within groups based on time between assessments, sex, and order of assessment type (DMA or BPH first) were analysed. Four groups based on time between assessments were analysed: 0–1 year (up to 365 days intervening, N = 591), 1–2 years (366–730 days, N = 250), 2–3 years (731–1095 days, N = 148), and 3–4 years (1095–1460 days, N = 89). The correlation coefficients for each trait from each sex, groups of dogs that had carried out DMA or BPH first, and the different time-interval groups were compared by transforming the coefficients to z-scores (Fisher's z-transformation), whereafter the significance of the differences was tested using a single-sided test (Lenhard and Lenhard, 2014).

To investigate the two-dimensional relationship between the corresponding DMA and BPH traits, a PCA was carried out where two components were extracted and the unrotated result was used. To confirm the result of the PCA, and to investigate the eventual presence of a circumplex in the data set, a MDS was carried out based on the 33 DMA protocol items and the 28 specific BPH traits from Svartberg (2021). If needed, the two dimensions were mirrored by multiplying the scores with − 1 to resemble the two-dimension space obtained in the PCA. The MDS analysis was carried out using nonmetric SMACOF for individual differences (three-way SMACOF) with the INDSCAL algorithm and 'torgerson' as the starting solution (De Leeuw and Mair, 2009).

The relationship to everyday behaviour was analysed in a correlation analysis between component scores and questionnaire data—21 subscales and 132 items—using Pearson product-moment correlation coefficients. When calculating component scores, the loadings from the PCA were used as weights on standardised trait values. For missing data in the correlation analyses, pair-wise deletion was used. Item/subscale correlations of $r \geq 0.15$ or $r \leq -0.15$ were considered as relevant (see Svartberg, 2021).

2.4. Software

Most of the analyses were performed using R statistical software (R Core Team, 2021). For the internal consistency analysis, and for the conversion of correlations to Euclidean distances for the MDS analysis, the psych package was used (Revelle, 2016), whereas the MDS analysis was performed using the smacof package (De Leeuw and Mair, 2009). In addition, STATISTICA was used for calculations of Pearsons product-moment correlations and for the PCA (StatSoft, Inc, 2013). Pairwise comparisons between correlation coefficients were performed with the Psychometrica online calculator (Lenhard and Lenhard, 2014). The figures were made in MS PowerPoint based on originals from MS Excel.

3. Results

3.1. Internal consistency of the traits

Cronbach's alpha could be calculated for 54 of the 59 aggregated variables (the remaining five had too few RV to calculate the alpha value). For these, alpha ranged from 0.69 to 0.97 except for Boldness, which had $\alpha = 0.57$. The average inter-item correlations for all aggregated variables ranged from 0.30 to 0.97. Taken together, these estimates indicate acceptable internal consistency for the aggregated variables (see supplementary materials, S4 for all estimates).

3.2. Correlations between corresponding traits

The corresponding traits were all statistically significantly correlated with $p < 0.001$ (Table 1). The highest correlations were found for Playfulness and Boldness with coefficients close to $r = 0.60$, whereas the lowest correlation was found for Aggressiveness with $r = 0.25$. No differences in correlations for corresponding traits were found related to sex or order of assessment.

3.3. Differences in correlations related to sex, type of first assessment, and time between assessments

No statistically significant differences were found between correlations for males and females, or between correlations for the groups of dogs that had been assessed with the DMA or BPH first (Table 1). The comparison of correlations related to time between assessments revealed statistically significant differences for three of the traits: Playfulness, Curiosity/fearlessness (DMA)/Non-social fearfulness (BPH) and Boldness. All were related to a higher correlation for dogs that were assessed within the shortest time interval 0–1 year (Fig. 1, Table 2). For Curiosity/fearlessness/Non-social fearfulness, the correlation within the group of dogs that carried out the assessments within a year ($r = 0.58$) was higher than for the group of dogs that were assessed for the second time 1–2 years later ($r = 0.44$), 2–3 years later ($r = 0.46$), and 3–4 years later ($r = 0.39$). For Playfulness, the correlation for the dogs that were assessed a second time within a year ($r = 0.64$) was higher than the 3–4 years group ($r = 0.43$). For Boldness, the correlation for the 0–1 year group ($r = 0.63$) was higher compared to the 1–2 years group ($r = 0.49$). Despite these differences, the correlations within all groups were statistically significant, indicating rank-order consistency between assessments even for longer time intervals.

3.4. Principal component analysis on corresponding traits

A PCA was carried out based on corresponding traits from the DMA and the BPH. The Bartlett's test of sphericity ($\chi 2 = 10217$, df = 45, $p < 0.001$) indicated that the data set was appropriate for PCA. The correlation matrix was not positive definite; smoothing was done by adjusting the eigen values. Due to the question at issue, two components

Table 1
Correlation coefficients (Pearson product-moment correlations) with p-values for the five corresponding traits from the DMA and the BPH and the results from the group wise single-sided significance test of the difference between them regarding order of assessment type and sex. (R) indicates that a reversal was done before analysis.

			Comparison regarding order of assessment type						Comparison between males and females					
	Total sample (N = 1078)		DMA first (N = 671)		BPH first (N = 407)		Diff. between correlations		Males (N = 499)		Females (N = 579)		Diff. between correlations	
Trait	r	p	r	p	r	p	z	p	r	p	r	p	z	p
Sociability	0.47	<0.001	0.48	<0.001	0.44	<0.001	0.88	0.190	0.47	<0.001	0.46	<0.001	0.11	0.458
Playfulness	0.59	<0.001	0.58	<0.001	0.62	<0.001	-1.02	0.153	0.57	<0.001	0.60	<0.001	-0.52	0.300
Curiosity/fearlessness / Non-social fearfulness (R)	0.51	<0.001	0.52	<0.001	0.49	<0.001	0.52	0.300	0.53	<0.001	0.48	<0.001	1.04	0.150
Aggressiveness	0.25	<0.001	0.26	<0.001	0.24	<0.001	0.37	0.356	0.27	<0.001	0.24	<0.001	0.46	0.322
Boldness	0.57	<0.001	0.58	<0.001	0.56	<0.001	0.47	0.319	0.57	<0.001	0.57	<0.001	0.12	0.451

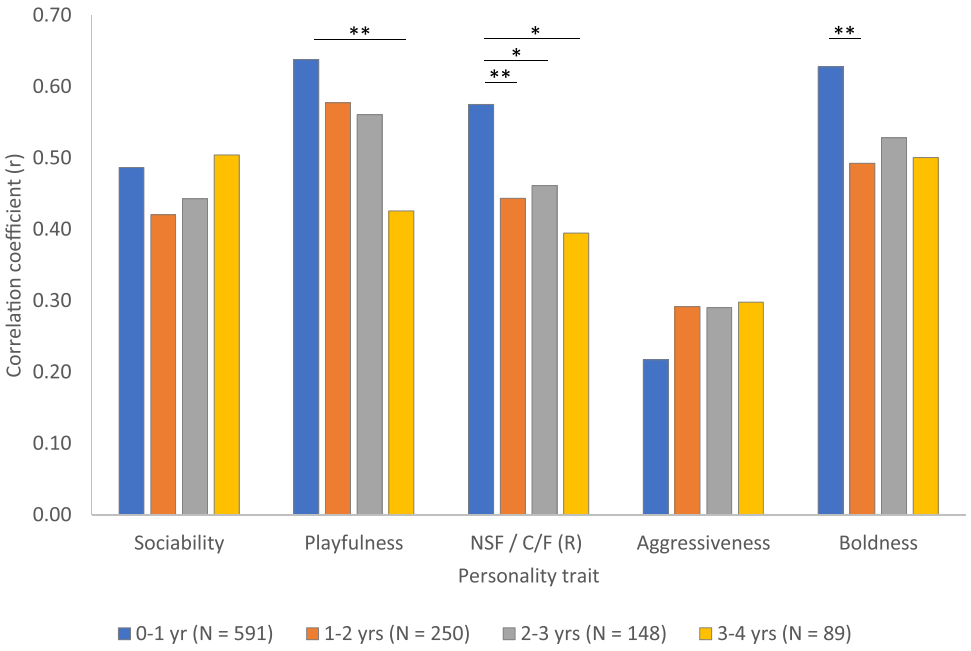

Fig. 1. Correlation coefficients (Pearson product-moment correlations) for the five corresponding traits from the Dog Mentality Assessment (DMA) and the Behavioural and Personality Assessment in Dogs (BPH) in groups of dogs based on time between assessments. NSF = Non-social fearfulness (BPH); C/F = Curiosity/fearlessness (DMA); (R) indicates that a reversal was done before analysis. Asterisks indicate level of statistical significance between coefficients: * $p < 0.050$; * * $p < 0.010$; * ** $p < 0.001$. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

Table 2
The result of the single-sided significance test from the group-wise comparison of correlation coefficients based on time between assessments. (R) indicates that a reversal was done before analysis. Values in bold indicates statistically significant differences.

	0–1 yr vs						1–2 yrs vs				2–3 yrs	
	1–2 yrs		2–3 yrs		3–4 yrs		2–3 yrs		3–4 yrs		3–4 yrs	
Trait	z	p	z	p	z	p	z	p	z	p	z	p
Sociability	1.10	0.137	0.60	0.273	-0.20	0.420	-0.26	0.398	-0.85	0.198	-0.58	0.280
Playfulness	1.27	0.103	1.30	0.097	**2.59**	**0.005**	0.23	0.408	1.63	0.052	1.32	0.094
Curiosity/fearlessness / Non-social fearfulness (R)	**2.36**	**0.009**	**1.68**	**0.046**	**2.06**	**0.020**	-0.21	0.415	0.47	0.318	0.60	0.274
Aggressiveness	-1.06	0.146	-0.84	0.199	-0.75	0.227	0.02	0.493	-0.05	0.479	-0.06	0.476
Boldness	**2.62**	**0.004**	1.62	0.053	1.63	0.052	-0.46	0.322	-0.09	0.466	0.28	0.391

were extracted. They explained in total 53.8 % of the total variance (40.7 % and 13.1 %, respectively), with eigenvalues of 4.07 and 1.31, respectively. The first component was positively loaded > 0.4 by Boldness, Sociability, Playfulness from both the DMA and the BPH and by Curiosity/fearlessness from the DMA, and negatively < −0.4 by Non-social fearfulness from the BPH (Fig. 2; supplementary materials, S4). The second component was loaded positively > 0.4 by Aggressiveness from both assessments. Some cross-loadings were found. Playfulness loaded 0.37 (DMA) and 0.29 (BPH) on the second component, Sociability from the BPH loaded − 0.35 on the second component, whereas Aggressiveness from the BPH loaded − 0.25 on the first component.

3.5. Multidimensional scaling based on protocol items from the DMA

The MDS analysis based on the 33 DMA items and the 28 specific BPH traits converged after 198 iterations, and the stress value for two dimensions was 0.18 (Fig. 3). Items from both assessments related to play, chase, social contact and exploration had high dimension-1 scores. Items related to avoidance, remaining avoidance, and startle reaction from the DMA, whereas BPH traits related to fear, anxiety, avoidance as well as aggression scored low. The second dimension was characterised by high scores from aggression-related variables from the DMA and a low score for Disinterest from the BPH. Furthermore, Handler contact in the Food interest subtest (BPH), Attention in the Ghost subtest (DMA), and Noise exploration (BPH) scored high. Disinterest, Submissiveness, and Imposing from the BPH had low dimension-2 scores. All MDS scores are presented in supplementary materials (S4 and S5).

Some items were related to both dimensions. For example, the chase items following and grabbing had, in addition to high scores on the first dimension, also relatively high scores on the second dimension, whereas variables related to remaining fear from both assessments, as well as fear-related variables from the Surface subtest in the BPH, had low scores on both dimensions. Items related to social contact and greeting from the first subtest in the two assessments had high scores on the first dimension and low scores on the second. Handling avoidance, Handling anxiety, and Approaching person aggression from the BPH had low scores on the first dimension and high scores on the second.

3.6. The relationship between component scores and questionnaire data

To relate the two-dimensional space to everyday behaviour, a correlation analysis was carried out between component scores derived from the PCA and variables from the questionnaire (21 subscales and 132 items). Fourteen subscales and 49 of the questionnaire items were correlated with one or both components with $r \geq 0.15$ or $r \leq -0.15$, presented in Fig. 4 and Table 3. Ten subscales and 38 items were correlated with only one of the components, such as the negative correlation between subscales nonsocial fear, noise-related fear and fear recovery latency and component 1, and the same component's positive correlation with exploration tendency. Fifteen questionnaire variables were correlated with both components. For example, stranger-directed interest reached high positive correlations with component 1, but had also a correlation of $r < -0.15$ with the second component, whereas Human-directed play interest had a high positive correlation with

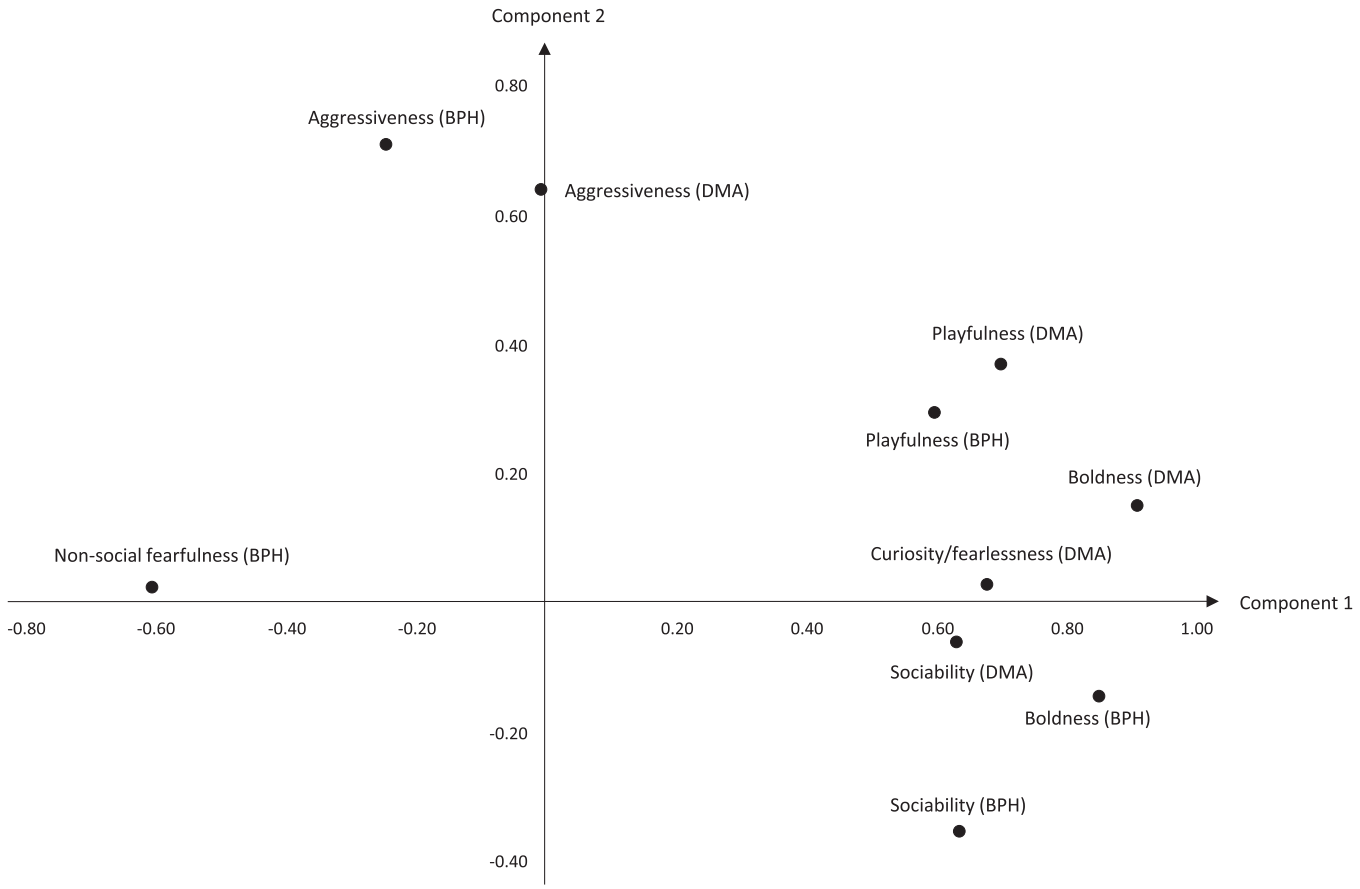

Fig. 2. Loadings of the corresponding traits from the Dog Mentality Assessment (DMA) and the Behaviour and Personality Assessment in Dogs (BPH) on the two extracted components from the principal component analysis.

component 1 and a correlation of $r > 0.15$ with component 2. For stranger-directed aggression and stranger-directed fear, a combination of negative correlations with component 1 and positive component 2 correlations was evident. See supplementary materials (S4 and S6) for all correlations.

4. Discussion

In this study, data from 1078 dogs that had carried out both the DMA and the BPH were analysed. Moderate to high correlations were found between corresponding traits from the DMA and the BPH, even with up to four years between assessments. This implies that the two assessments measure similar aspects of the dog's personality with temporal stability over longer periods of time. Two major dimensions were detected. The first was correlated positively with object play, pro-social behaviour, and exploration, and negatively with variables related to fear. The second dimension was mainly correlated with variables related to aggression. The correlation pattern for data from a questionnaire with items related to everyday behaviour was in line with the results from the two assessments.

Four of the traits from the DMA and the BPH that were assumed to correspond—namely, Playfulness, Sociability, Non-social fearfulness (versus Curiosity/fearlessness, reversed, in the DMA) and Boldness—were highly correlated, with coefficients between $r = 0.47$ and $r = 0.59$. This result suggests that they are corresponding traits and represent the same aspects of dog personality. The correlation between DMA and BPH Aggressiveness, the fifth investigated trait, was $r = 0.25$, which indicates a somewhat weaker correspondence. One possible partial explanation for this may be differences in the stimuli use in the two assessment types. For example, the DMA 'ghosts' are dressed such that they may be difficult to interpret as persons and have in addition fake eyes, whereas the approaching person in the BPH may be perceived as a human being to the dog. Persons with distorted appearance and staring persons have been found to elicit threatening behaviour to a higher degree than normally dressed persons (van den Berg et al., 2003; Ott et al., 2008; Haverbeke et al., 2009; van der Borg et al., 2010). Another possible reason for the lower correlation for Aggressiveness is differences in assessment. Observations have been made that the measures of aggression in the DMA reflect to some extent an agitated state in the dog, e.g., excited barking without signs of threat (C. Blixt, personal communication). To get a more reliable and specific assessment in the BPH, threatening behaviour is more precisely defined and the raters are trained to consider the dog's degree of 'anger' (Svartberg, 2021). Thus, aggressiveness from the two assessments may represent somewhat different aspects of threatening behaviour.

No differences were found between correlations regarding sex or type of first assessment. However, differences were found in correlations for Boldness, Playfulness, and Non-social fearfulness (Curiosity/fearlessness) regarding time between assessments, which all were related to the group of dogs assessed in a short time interval (up to one year in between). This indicates a higher stability when assessed again shortly after the first assessment, but it also implies a considerable stability over time, since no differences were found between the other groups with up to four years between assessments. The same applies to Sociability and Aggressiveness, where no differences related to time between assessment were found. Three DMA in a test series with one month in between resulted in correlations of > 0.5 for all traits (Svartberg et al., 2005). Even though lower correlations were found for Aggressiveness overall, the current results indicate that high rank-order stability is maintained for longer periods, as well.

Fig. 3. The result from the multidimensional scaling analysis of the 33 DMA protocol items and the 28 specific BPH traits. The DMA protocol items are numbered (e.g., '8c. Avoidance'), whereas the BPH trait labels are without numbers (e.g., 'Gunshot fear').

There are several similarities in the two-dimensional spaces obtained from the PCA and the MDS analyses, which are supported by the correlation pattern of the questionnaire data. The first component in the PCA as well as the first dimension in the MDS analysis (henceforth both are referred to as D1) were correlated negatively with DMA and BPH variables related to fear from both social and non-social subtests. In line with this, negative correlations were found between D1 and questionnaire subscales related to fear, e.g., stranger-directed fear, nonsocial fear, and fear-recovery latency. Thus, a common denominator for the negative end of D1 seems to be fear, expressed in a wide range of situations (e.g., Boissy, 1995; Svartberg, 2021). Positive correlations were found mainly for variables related to object play in social and non-social situations, exploration, and social greeting and interaction. In animals, play is assumed to be a self-rewarding and has been associated with the feeling of joy (Burghardt, 2005; Panksepp, 2011). In dog training, object play is commonly used as a reward (e.g., Hiby et al., 2004; Porritt et al., 2015; Gerencsér et al., 2018). Exploration has been associated to positively valenced emotions such as anticipation, curiosity, and interest (Panksepp, 2011), and has been suggested to be self-rewarding in animals and a relevant indicator of well-being (Boissy et al., 2007). Social contact and interactions with group members are linked to positive affect in group living species (Van Ree et al., 2000). As an effect of domestication, dogs have social skills and bond-forming abilities that enable complex interactions not only with conspecifics, but also with humans (Topál et al., 1998, 2005; Palmer and Custance, 2008), and may in some situations even prefer interaction with unfamiliar persons over their owners (Feuerbacher and Wynne, 2017). Based on this, the dog's interaction with the unknown person in the assessment situation is likely associated with positively valenced emotions, an assumption that is supported by a previously observed correlation between DMA Sociability and optimistic judgement bias (Barnard et al., 2018). Thus, it seems that the first dimension may be interpreted in terms of affective valence, from an unpleasant to a pleasant emotional state, a dimension previously suggested for animals in general (Mendl et al., 2009, 2010; Anderson and Adolphs, 2014) and applied to dogs (e.g., Burman et al., 2011; Travain et al., 2016; Albuquerque et al., 2018).

The second component and dimension (D2) was positively correlated to aggression-related variables, especially from the DMA but also from the BPH, which according to the definitions (Svartberg and Forkman, 2002; Svartberg, 2021) can be characterised as offensive as well as affective (Blanchard and Blanchard, 2003; Panksepp and Zellner, 2004). However, several other variables were associated with D2 as well, which makes it likely that it represents a broader, aggression related, concept. One such concept is impulsivity, which has been identified as a stable personality dimension in animals (Locurto, 2007; Réale et al., 2007; Freeman and Gosling, 2010), including dogs (Riemer et al., 2014; Fadel et al., 2016). Besides aggressive behaviour, impulsivity has been associated in dogs with excitement proneness, high responsiveness, hyperactivity, and low self-control (Reisner et al., 1996; Vas et al., 2007; Wright et al., 2011; Amat et al., 2013; Piotti et al., 2018; Sulkama et al., 2021). Another concept related to aggression is coping style, which refers to individual differences in behavioural and physiological reactions to challenging situations. A proactive coping style is characterised by a high level of aggression and a proneness to take risks, whereas reactive

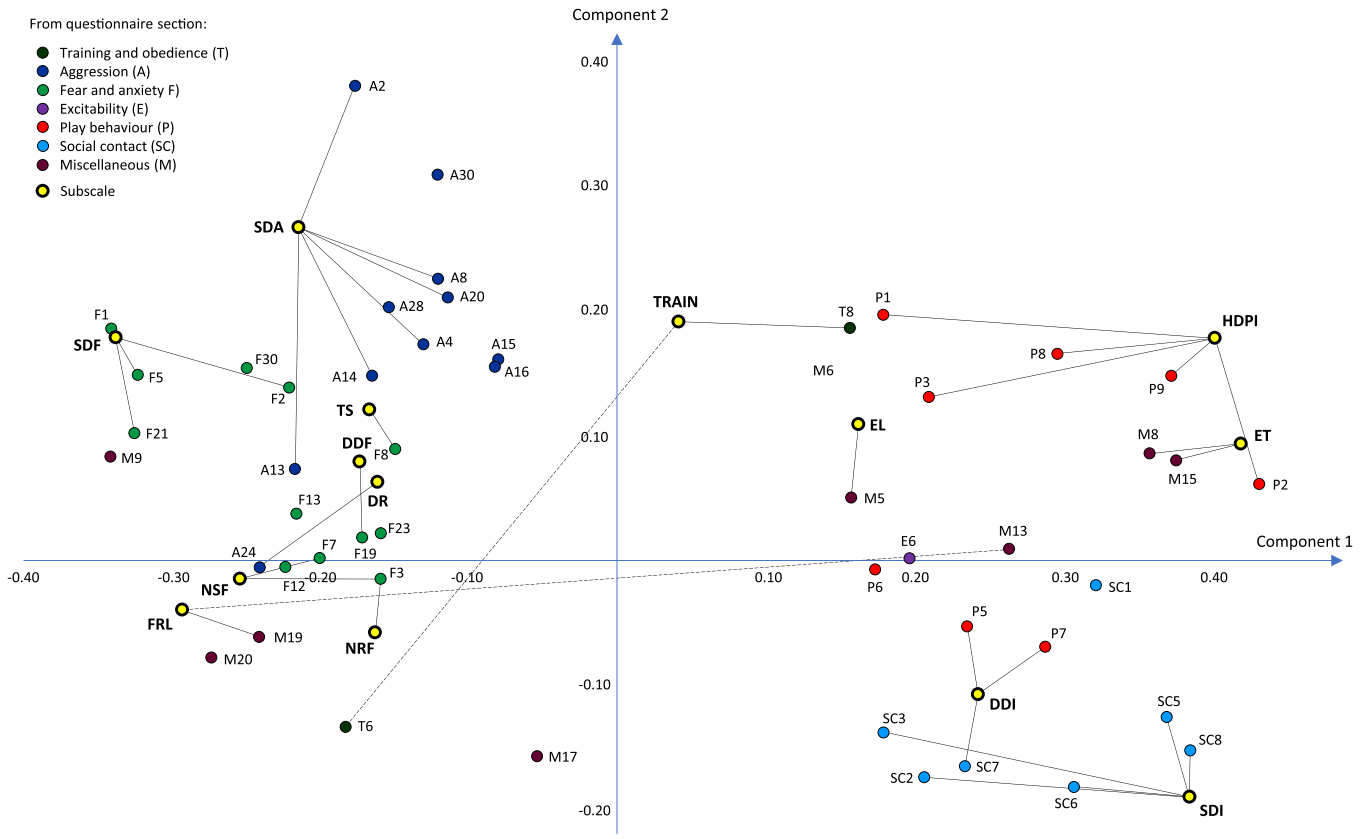

Fig. 4. The result from the correlation analysis between questionnaire data and component scores from the PCA. Lines indicate association between items and subscales (in bold); filled lines positive relationship, dotted line negative relationship. Fourteen subscales reached $r \geq 0.15$ or $r \leq -0.15$ with at least one of the components: dog-directed fear (DDF), dog-directed interest (DDI), dog rivalry (DR), energy level (EL), exploration tendency (ET), fear recovery latency (FRL), human-directed play interest (HDPI), noise-related fear (NRF), nonsocial fear (NSF), stranger-directed aggression (SDA), stranger-directed fear (SDF), stranger-directed interest (SDI), touch sensitivity (TS), trainability (TRAIN). Forty-nine items reached $r \geq 0.15$ or $r \leq -0.15$, see Table 3 for the items and the abbreviations of them.

coping is associated with non-aggressiveness and passive strategies when challenged (Koolhaas et al., 2010; De Boer et al., 2015). Proactive coping style, defined as a tendency towards high activity, barking and short attack latency, has been identified in dogs (Horváth et al., 2007). A relationship between impulsivity and coping style has been indicated, since proactive individuals have been found to be more impulsive in decision-making, and more easily frustrated compared to reactive individuals (David et al., 2004; Steimer and Driscoll, 2005). The characteristics of the high end of D2—e.g., threatening behaviour, intense attention towards the approaching ghosts, and the fast pursuit after a 'fleeing' rag in the chase subtest—may indicate an association with impulsivity as well as a proactive coping style. The same goes for the low end: the questionnaire subscale 'usually becomes passive when it is scared' (M17) may indicate a tendency towards low impulsivity, but also to a reactive coping style. Furthermore, the association with Disinterest in the BPH, which assesses the dog's general exploration of things other than the assessment stimulus, may be due to a sensitivity to details, which has been associated with a reactive coping style (Benus et al., 1990; Nicolaus et al., 2015). However, low responsiveness to the assessment stimuli may also be due to low impulsivity. None of the concepts matches perfectly with the present results regarding D2. Proactive coping style is associated with exploration and boldness, which in this study is related to D1. However, a differentiation of coping style aspects has been suggested, where the strategy in qualitative terms should be separated from other aspects, such as fearfulness and sociability (Koolhaas and Van Reenen, 2016), which is in line with the present results. An impulsivity interpretation could be questioned since the questionnaire-subscale excitability, a tendency central to impulsivity, did not correlate with D2. This may, however, be explained by the subscale items, which are limited to excitement in the home environment. Previous results suggest that some of the C-BARQ subscales, of which excitability is one, seem to be predictive of situations only in well-known home situations (Svartberg, 2005, 2021). Thus, if D2 reflects a tendency towards impulsivity, it is of a type that is expressed in novel situations of a challenging character.

If an interpretation of D2 in terms of impulsivity or coping style is justified, there seems to be an association with arousal for the dimension. Aggression is characterised by high arousal in mammals in general (Marler, 1976; Panksepp and Zellner, 2004). Arousal seems to play a significant role in the expression of impulsivity in dogs (Reisner et al., 1996; Wright et al., 2011), and on a state level has been suggested to correspond to impulsivity at a personality trait level in humans (Strus et al., 2014; Strus and Cieciuch, 2017). Furthermore, a positive correlation between proactive coping and arousal of the sympathetic nervous system has been found in different animal species (Koolhaas et al., 2010; Krause et al., 2017). Thus, it is possible that the second dimension may reflect arousal, as the dimension complementary to valence does in the CMA (Russell, 1980, 2003) and in the framework proposed by Mendl et al. (2010). What seems to contradict an interpretation in terms of arousal are the low scores for sociality-related variables, as high sociability in the assessments is characterised by intense greeting. However, intense greeting is uncommon in the assessments: Only 1–8 % of the scores for greeting intensity or social contact are on the highest level (see supplementary materials, S7). Most of the scores represent a calm greeting response or acceptance to be handled, which indicates that the assessed social behaviour is mainly related to friendly and calm

Table 3
The questionnaire items that correlated with $r \geq 0.15$ or $r \leq -0.15$ with at least one of the components (C) from the PCA. DDA = dog-directed aggression, EX = excitability. For abbreviations of the remaining subscales, see caption for Fig. 4. Note: some of the items are shortened; see supplementary materials, S6, for full items.

Section	Item	Abbr.	Subscale	Corr. with	
				C1	C2
Training and obedience	Slow to learn new tricks or tasks	T6	TRAIN (-)	-0.18	-0.13
	Fetch or attempt to fetch sticks, balls and other objects	T8	TRAIN (+)	0.16	0.19
Aggression	When approached by unfamiliar adult while being walked	A2	SDA	-0.18	0.38
	Toward unfamiliar persons approaching the dog in your car	A4	SDA	-0.13	0.17
	When unfamiliar persons approach a family member away from home	A8	SDA	-0.12	0.23
	When an unfamiliar person tries to touch or pet the dog	A13	SDA	-0.22	0.07
	When joggers, cyclists, etc. pass your home while your dog is outside	A14	SDA	-0.17	0.15
	When approached by an unfamiliar male dog while being walked	A15	DDA	-0.08	0.16
	When approached by an unfamiliar female dog while being walked	A16	DDA	-0.08	0.16
	Toward unfamiliar persons visiting your home	A20	SDA	-0.11	0.21
	Towards another familiar dog in your household	A24	DR	-0.24	-0.01
	When surprised by an unfamiliar person	A28	–	-0.15	0.20
	When approached by a person that looks strange/moves strangely	A30	–	-0.12	0.31
Fear and anxiety	When approached by an unfamiliar adult away from your home	F1	SDF	-0.34	0.19
	When approached by an unfamiliar child away from your home	F2	SDF	-0.22	0.14
	In response to sudden or loud noises	F3	NSF/NRF	-0.16	-0.01
	When an unfamiliar person tries to touch or pet the dog	F5	SDF	-0.32	0.15
	In response to strange or unfamiliar objects on or near the sidewalk	F7	NSF	-0.20	0.00
	When examined/treated by a veterinarian	F8	TS	-0.15	0.09
	When first exposed to unfamiliar situations	F12	NSF	-0.22	0.00
	When once again exposed to a situation where the dog showed fear	F13	–	-0.22	0.04
	When unfamiliar dogs visit your home	F19	DDF	-0.17	0.02
	When surprised by an unfamiliar person	F21	–	-0.33	0.10
	When surprised by something in the surroundings	F23	–	-0.16	0.02
	When approached by a person that looks strange/moves strangely	F30	–	-0.25	0.15
Excitability	When visitors arrive at your home	E6	EX	0.20	0.00
Play behaviour	Is eager to play with family members	P1	HDPI	0.18	0.20
	Is eager to play with strangers	P2	HDPI	0.43	0.06
	Retrieves play objects and initiates play	P3	HDPI	0.21	0.13
	Is eager to play with other female dogs	P5	DDI	0.23	-0.05
	Enjoys play-wrestling	P6	–	0.17	-0.01
	Is quick to respond to other dogs play invitations	P7	DDI	0.29	-0.07
	Enjoys tug-of-war with familiar persons	P8	HDPI	0.29	0.17
	Is eager to run after thrown balls	P9	HDPI	0.37	0.15
Social contact	Loves being the center for attention	SC1	–	0.32	-0.02
	Greets visiting adults in a friendly manner	SC2	SDI	0.21	-0.17
	Greets visiting children in a friendly manner	SC3	SDI	0.18	-0.14
	Is eager to approach adults away from home in a friendly manner	SC5	SDI	0.37	-0.13
	Is eager to approach children away from home in a friendly manner	SC6	SDI	0.31	-0.18
	Is eager to approach dogs away from home in a friendly manner	SC7	DDI	0.23	-0.16
	Enjoys being petted by strangers	SC8	SDI	0.38	-0.15
Miscellaneous	Is playful, puppyish, boisterous	M5	EL	0.16	0.05
	Is very curious	M8	ET	0.36	0.09
	Usually runs away when getting scared	M9	–	-0.34	0.08
	Quickly overcome its fear after being scared	M13	FRL (-)	0.26	0.01
	Usually approaches and examines if something unexpected happens	M15	ET	0.37	0.08
	Usually becomes passive when it is scared	M17	–	-0.05	-0.16
	Usually takes time to get back to a normal state after being scared	M19	FRL (+)	-0.24	-0.06
	Often becomes passive/introvert when exposed to unfamiliar situation	M20	–	-0.27	-0.08

interaction. Further studies may shed light on the relationship between D2 and established measures of impulsivity, such as the Dog Impulsivity Assessment Scale (Wright et al., 2011), as well as to physiological arousal.

The interpretation of the two dimensions in terms of valence and arousal makes it interesting to compare the current result with the relationship between affect and FFM personality. Neuroticism has repeatedly been associated with the unpleasant end of the valence dimension close to 9 o'clock in the CMA, using the metaphor of a clock-face (Yik and Russell, 2001; Yik et al., 2002, 2011; Strus et al., 2014; Strus and Cieciuch, 2017). This is consistent with current results based on the assumption that Boldness, the core of D1, is negatively related to Neuroticism (Svartberg and Forkman, 2002; Svartberg, 2021). In humans, Extraversion has been associated with a pleasant state together with high arousal, located in the CMA space at approx. 2 o'clock (Yik and Russell, 2001; Yik et al., 2002, 2011; Strus et al., 2014; Strus and Cieciuch, 2017). Variables related to social object play, chase-proneness, trainability, and energy level are in this area in the current space, aspects that may be signs of Extraversion in dogs (Gosling and John, 1999; Gosling et al., 2003). In humans, Extraversion is also associated with sociability via the lower-order trait affiliation and the aspects of warmth and gregariousness (McCrae and John, 1992; Depue and Collins, 1999). However, warmth, together with other pro-social aspects such as friendliness, cooperativeness, and kindness, are related to high Agreeableness as well (Graziano and Eisenberg, 1997; John and Srivastava, 1999). Agreeableness have been located at approx. 4 o'clock in the CMA (Yik et al., 2011; Strus et al., 2014; Strus and Cieciuch, 2017), which is in correspondence with the location of variables related to pro-social behaviour in the current study. Thus, it is possible that Sociability in the DMA and the BPH, as well as the questionnaire subscale stranger-directed interest, may reflect a canine equivalent of Agreeableness. This agrees with the counterposed location of the space for stranger-directed aggression and BPH variables related to a negative attitude towards persons, which could represent hostility, the opposite

of agreeableness.

Taken together, it is possible that the two dimensions identified at a state level may reflect degree of valence and arousal, as in the models of Russell (1980, 2003) and Mendl et al. (2010). At a trait level, the first dimension may reflect boldness, whereas the second dimension seems to be associated with impulsivity as well as coping strategy. The two-dimensional space may be seen as a quasi-circumplex with a circular arrangement of variables (Tracey, 2000). Circumplex models are appropriate in the description of differences in degree of similarity between variables and have been used fruitfully in the study of personality and emotions in humans (e.g., Plutchik and Conte, 1997). The results in the current study may be a possible basis for a dog affect and personality circumplex that can be used to summarise the dog's behaviour in the assessment. Such a model, approximately interpreted in Fig. 5 based on the results and their discussion, may have several applications, such as in the understanding of the individual dog's personality and its relationship to emotional predispositions, in mapping different problem-causing behaviours, in prediction of work and service suitability, and in comparisons between dog breeds or genetic lines. Provided a genetic basis, further applications are possible, such as in behavioural-based dog breeding, and further scientific investigations may be fruitful, especially in the search for links between genetic variants and affect-related behaviour in dogs. The similarities with the human-integrative frameworks CMA and the Circumplex of Personality Metatraits (Strus et al., 2014; Strus and Cieciuch, 2017) open for comparative studies with testable hypotheses. One example is a possible relationship to the interpersonal circumplex (Wiggins, 1979), which previously has been applied to dogs (Zeigler-Hill and Highfill, 2010). Another is welfare and well-being, in which long-term affective states are central (Mendl et al., 2009; Dawkins, 2017).

There are some possible limitations in this study. The data were collected at several assessment sites by several raters. Even though a study on the interrater reliability in the BPH indicated good agreement between raters (Svartberg, 2021), the varying conditions may have affected the reliability of the data. Another possible issue is that some of the questionnaire data were received after the assessment in the DMA or the BPH. In these cases, the owner may have been influenced by the dog's behaviour in the DMA/BPH when answering the questionnaire, which opens for a possible risk that the data sets were not completely independent. A general possible limitation of the usefulness of the two-dimensional space is that it is based on data from the DMA and the BPH, i.e., from experimental situations, which may reflect only specific aspects of dog behaviour. Even though the results from the analysis of questionnaire data are in support for generalisability outside the assessment situation, there are likely other behavioural aspects not included in this study that may be of relevance from both an affect and a personality point-of-view.

5. Conclusions

The results presented in this study indicate that a similar array of personality traits with long-term stability is detected by the DMA and the BPH. The relationships between the traits suggest a two-dimensional space that can be defined not only from a trait perspective, but also from an affective state perspective. At an affective state level, the dimensions seem to represent valence and arousal, while at a personality trait level they seem to reflect boldness and impulsivity. The second dimension may also reflect coping strategy in challenging situations. Thus, the

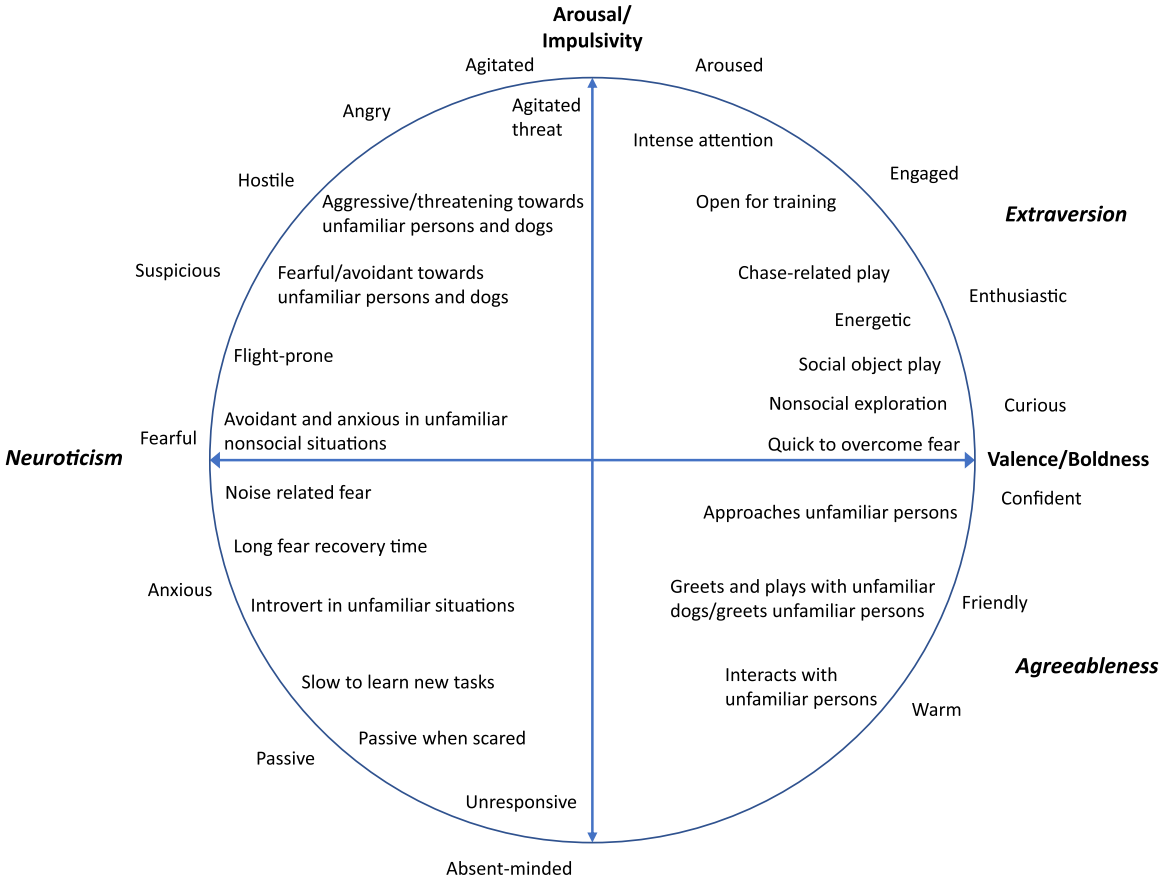

Fig. 5. An approximate interpretation of the detected two-dimensional space that are assumed to reflect core affect in dogs at a state level (valence and arousal) and personality at a trait level (boldness and impulsivity). Behavioural indicators inside the circle, suggested emotion-related states outside the circle, and suggested relation to Five-Factor Model personality traits in bold italics.

personality traits detected by the DMA and the BPH may, at least partly, be defined as individual differences in affective predispositions. The results may be used to elaborate a personality- and affect-related model in dogs based on the two assessment methods with several possible applications. Dogs of different breeds or different selection purposes may be compared, and factors related to functionality can be identified. Behaviour that may lead to problems for the owner or the dog can be identified in a more detailed way. Furthermore, welfare problems related to different personalities may be identified, where actions can be taken to improve well-being. In addition, the model may be used as a platform for future studies of dog behaviour in areas such as genetics, emotions, welfare, and mental health.

Declaration of Competing Interest

The author was one of the developers of the BPH and served as a consultant for the SKC during the development process.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2022.105740.

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