

**UNIVERSIDAD COMPLUTENSE DE MADRID
FACULTAD DE PSICOLOGÍA**



TESIS DOCTORAL

**Social motivation in the dog in the context of domestication,
and its association with sociability and social cognition**

**(Motivación social en el perro en el contexto de la
domesticación, y su relación con la sociabilidad y la cognición
social)**

MEMORIA PARA OPTAR AL GRADO DE DOCTOR

PRESENTADA POR

Mónica Cristina Boada Maza

Directores

**Fernando Colmenares Gil
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Madrid

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PROGRAMA DE DOCTORADO EN PSICOLOGÍA



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SUMMARY

Human-directed social motivation plays a central role in the domestication process. The human self-domestication hypothesis establishes a correspondence between human evolution and domestication by proposing that humans, like domestic species, experienced a selection for prosociality (understood as positive social interactions) and against aggression, that led to the emergence of correlated traits at the anatomical, physiological, behavioural and cognitive level (i.e., the domestication syndrome; DS) (Hare, 2017). Similarly to humans, dogs have been claimed to possess an hypertrophied social motivation (vonHoldt et al., 2017). Having shared a niche with humans for an extended period of time, dogs might have experienced evolutionary convergence with humans (Ádám Miklósi et al., 2007).

Therefore, dogs are a particularly interesting model species to study social motivation. A more elaborated conceptualization and evaluation of social motivation towards humans in dogs can be valuable for a better understanding of the changes that dogs have undergone during domestication, which might also have occurred in human evolution. To do this, we adopted as a working strategy the conceptual framework of social motivation devised by Chevallier et al. (2012), who proposed that, in humans, there are three types of behavioural manifestations of social interest: 1) social orienting, 2) social reward, and 3) social maintaining. Moreover, it is important to clarify how this conceptualization relates to sociability in a narrow sense, i.e., the tendency to approach and interact with unfamiliar humans positively, and in a broad sense, i.e., as a personality trait. In addition, if heightened social motivation and complex social cognition are DS traits, they should be intercorrelated.

The main objective of this project was to assess social motivation and its possible associations with sociability and social cognition in dogs. We evaluated 104 pet dogs evaluated in a test battery that assessed several social behaviours used as indicators of the three components of social motivation (social orienting, reward and maintaining), as well as of their sociability (which was also measured through a personality questionnaire) and their social cognition. This major part of the project thus had three goals: 1) studying the association between the hypothesised behavioural manifestations of social motivation, 2) evaluating the relationship between sociability and these manifestations, and 3)

determining if individual differences in sociability and/or social motivation are associated with variation in socio-cognitive abilities. Our research aimed to test the following three general hypotheses:

1. The three categories of social motivation proposed in humans can be supported empirically in dogs, and they indeed represent behavioural manifestations of the same construct.
2. There is a positive association between social motivation and sociability.
3. There is a positive association between social motivation/sociability and social cognition.

A secondary goal of the study was exploring whether the subjects could be classified into profile types based on their scores on behavioural measures of social motivation and sociability. This analysis might reveal profiles that differ on their degree of consistency across contexts (i.e., their contextual plasticity). Here we had no a priori hypothesis to test.

Regarding the first hypothesis, this study revealed no evidence of the existence of three dimensions of human-oriented social motivation in dogs, i.e., social orienting, social reward and social maintaining. The pattern of correlations across putative social motivation tests we found prevented us from conducting a factor analysis. The lack of correlations might imply that the social motivation tasks of our battery measured different traits, or that the behaviours expressed in these tests were not driven by a shared underlying motivational mechanism. Alternatively, the studied behaviours might still be valid indicators of social motivation, but the tests might have been inadequate for the study of individual differences or might not provide a clean measure, preventing us from finding existing associations. Another possibility is that, contrary to our assumptions, social motivation is not consistent across contexts, and is a context-specific trait instead.

Regarding the second hypothesis, we found limited evidence of an association between presumed behavioural manifestations of social motivation and behaviours during a commonly used sociability test in dogs. This might imply that behaviours in the social motivation tasks and in the sociability test were not driven by the same motivational mechanism. Alternately, one could hypothesize that these were all sociability-related behaviours and that our results suggest that their expression is context-specific. Dogs' behaviours during the sociability test were associated with their score on the personality

factors Fearfulness, Aggression towards People and Companionability as assessed with an abridged version of the Dog Personality Questionnaire (Amanda Claire Jones, 2008). This association might imply that the sociability test is influenced by and measures more than one personality trait.

As for the third hypothesis, we found few associations between performance in socio-cognitive tests and behaviours in social motivation and sociability tests. Our results provided little to no support for the DS hypothesis and other hypotheses linking sociability with interspecific socio-cognitive skills in dogs. Yet, several factors affect the interpretation of correlations and prevent us from concluding that our findings provide unequivocal evidence against the existence of a positive link between these constructs. Hence, the null findings of our study should be interpreted with caution.

Finally, we found suggestive evidence of the existence of clusters/profiles based on dogs' behaviours during the sociability test and across social motivation tasks. This supports the notion that individuals might differ on their contextual plasticity, with some clusters showing a high or low relative sociability/social motivation across all contexts, while others showed different sociability/social motivation levels depending on the context. Still, the validity and utility of the particular cluster solutions we found seems limited.

RESUMEN

La motivación social hacia los humanos juega un papel central en el proceso de domesticación. La hipótesis de la autodomesticación humana establece una correspondencia entre la evolución humana y la domesticación al proponer que los humanos, al igual que las especies domésticas, experimentaron una selección a favor de la prosocialidad (entendida como interacciones sociales positivas) y contra la agresividad, que condujo a la aparición de rasgos correlacionados a nivel anatómico, fisiológico, conductual y cognitivo (i.e., el síndrome de domesticación; SD) (Hare, 2017). De manera similar a los humanos, se ha afirmado que los perros poseen una motivación social hipertrofiada (vonHoldt et al., 2017). Habiendo compartido un nicho con los humanos durante un período prolongado de tiempo, los perros podrían haber experimentado una convergencia evolutiva con los humanos (Ádám Miklósi et al., 2007).

Por tanto, los perros pueden ser una especie modelo particularmente interesante para estudiar la motivación social. Una conceptualización y evaluación más elaborada de la motivación social hacia los humanos en el perro puede ser valiosa para una mejor comprensión de los cambios que los perros han experimentado durante la domesticación, que también podrían haber ocurrido en la evolución humana. Para ello, adoptamos como estrategia de trabajo el marco conceptual de motivación social ideado por Chevallier et al. (2012), quienes propusieron que, en humanos, existen tres tipos de manifestaciones conductuales del interés social: 1) orientación social, 2) recompensa social y 3) mantenimiento social. También es importante aclarar cómo esta conceptualización se relaciona con la sociabilidad en un sentido estricto, i.e., la tendencia a acercarse e interactuar con humanos desconocidos de manera positiva, y en un sentido amplio, i.e., como un rasgo de personalidad. Además, si una motivación social incrementada y una cognición social compleja son rasgos del SD, deben estar intercorrelacionados.

El objetivo principal de este proyecto fue evaluar la motivación social y sus posibles asociaciones con la sociabilidad y la cognición social en perros. Evaluamos 104 perros de familia en una batería de pruebas que valoraban varias conductas sociales utilizadas como indicadores de los tres componentes de la motivación social (orientación, recompensa y mantenimiento social), así como su sociabilidad (que también fue medida mediante un cuestionario de personalidad) y su cognición social. Esta parte principal del

proyecto tenía tres objetivos: 1) estudiar la asociación entre las hipotéticas manifestaciones conductuales de la motivación social, 2) evaluar la relación entre la sociabilidad y estas manifestaciones, y 3) determinar si las diferencias individuales en sociabilidad y/o motivación social están asociadas con la variación en habilidades socio-cognitivas. Nuestra investigación tuvo como objetivo contrastar las siguientes tres hipótesis generales:

1. Las tres categorías de motivación social propuestas en humanos pueden ser apoyadas empíricamente en perros, y en efecto representan manifestaciones conductuales del mismo constructo.
2. Existe una asociación positiva entre la motivación social y la sociabilidad.
3. Existe una asociación positiva entre la motivación social/sociabilidad y la cognición social.

Un objetivo secundario del estudio fue explorar si los sujetos podrían clasificarse en perfiles en función de sus puntuaciones en las medidas conductuales de motivación social y sociabilidad. Este análisis podría revelar perfiles que difieren en su grado de consistencia entre contextos (i.e., su plasticidad contextual). Aquí no teníamos ninguna hipótesis a priori que contrastar.

Con respecto a la primera hipótesis, este estudio no reveló evidencia de la existencia de tres dimensiones de motivación social orientada a los humanos en perros, i.e., orientación social, recompensa social y mantenimiento social. El patrón de correlaciones entre las supuestas pruebas de motivación social que encontramos no permitió realizar un análisis factorial. La falta de correlaciones podría implicar que las tareas de motivación social de nuestra batería medían diferentes rasgos, o que los comportamientos expresados en estas pruebas no tenían un mecanismo motivacional subyacente compartido. Alternativamente, los comportamientos estudiados podrían seguir siendo indicadores válidos de la motivación social, pero las pruebas podrían haber sido inadecuadas para el estudio de las diferencias individuales o podrían no proporcionar una medida limpia, lo que nos impidió encontrar asociaciones existentes. Otra posibilidad es que, contrariamente a nuestras suposiciones, la motivación social no es consistente en todos los contextos, y en su lugar es un rasgo que depende del contexto.

Con respecto a la segunda hipótesis, encontramos evidencia limitada de una asociación entre las presuntas manifestaciones conductuales de motivación social y los

comportamientos durante una prueba de sociabilidad comúnmente utilizada en perros. Esto podría implicar que las conductas en las tareas de motivación social y en la prueba de sociabilidad no tenían el mismo mecanismo motivacional. Alternativamente, se podría plantear la hipótesis de que todos estos eran comportamientos relacionados con la sociabilidad y que nuestros resultados sugieren que su expresión es específica para cada contexto. Las conductas de los perros durante la prueba de sociabilidad se asociaron con su puntuación en los factores de personalidad Miedo (*Fearfulness*), Agresividad hacia las personas (*Aggression towards People*) y Compañerismo (*Companionability*) evaluados con una versión abreviada del Cuestionario de Personalidad del Perro (*Dog Personality Questionnaire*) (Amanda Claire Jones, 2008). Esta asociación podría implicar que la prueba de sociabilidad está influenciada por y mide más de un rasgo de personalidad.

En cuanto a la tercera hipótesis, encontramos pocas asociaciones entre el desempeño en las pruebas socio-cognitivas y las conductas en las pruebas de motivación social y sociabilidad. Nuestros resultados proporcionaron poco o ningún apoyo para la hipótesis del SD y otras hipótesis que vinculan la sociabilidad con las habilidades socio-cognitivas interespecíficas en perros. Sin embargo, varios factores afectan a la interpretación de las correlaciones y nos impiden concluir que nuestros hallazgos proporcionan evidencia inequívoca contra la existencia de un vínculo positivo entre estos constructos. Por lo tanto, los hallazgos nulos de nuestro estudio deben interpretarse con cautela.

Finalmente, encontramos evidencia que sugiere la existencia de grupos/perfiles basados en las conductas de los perros durante la prueba de sociabilidad y en las tareas de motivación social. Esto apoya la idea de que los individuos pueden diferir en su plasticidad contextual, con algunos grupos mostrando una relativa alta o baja sociabilidad/motivación social en todos los contextos, mientras que otros mostraban diferentes niveles de sociabilidad/motivación social dependiendo del contexto. Aún así, la validez y utilidad de las soluciones de clústers particulares que encontramos parece limitada.

CHAPTER 1 – INTRODUCTION

1.1. DOMESTICATION

Although defining domestication seems a straightforward task, different conceptualizations of this phenomenon abound (e.g., Clutton-Brock, 1994; Per Jensen & Wright, 2014; Losey, 2022; Price, 1984; Purugganan, 2022; Zeder, 2012b). Here, I will adopt the definition provided by Per Jensen & Wright (2014), who see domestication as an evolutionary process “whereby populations of animals change genetically and phenotypically in response to the selection pressure associated with a life under human supervision” (p. 42). Indeed, an indisputable aspect of domestication is that it entails adaptation of a species to an artificial, human-modified environment that is associated with distinct selective pressures.

1.1.1. Evolutionary processes and domestication pathways

Selection of phenotypes and its associated genotypes is one of the main evolutionary drivers of the domestication process, along with inbreeding and genetic drift (Price, 1984, 1999, 2002). While the two latter mechanisms generate random changes and are expected to decrease genetic variability over time, selection provokes directional changes. Three selection processes can be distinguished: artificial selection, natural selection in captivity and relaxed selection, although the latter can be viewed as the absence of previous selection pressures instead of a selection process in itself (Per Jensen & Wright, 2014; Price, 1984, 1999, 2002).

In *artificial selection*, humans select the individuals that will breed based on unconscious biases or on the conscious interest on traits that they anticipate will be transmitted to the offspring; hence, artificial selection can be equated with selective breeding. This selective mechanism might be particularly relevant in late stages of the domestication process and might be related to the emergence of “improvement traits” (Larson & Fuller, 2014; Zeder, 2015).

Natural selection in captivity encompasses those selection pressures that are imposed by the captive environment but are independent of artificial selection. Some examples of the action of natural selection are differential mortality and reproductive success in captive populations independent of human action (Price, 2002). Pre-adaptations that have been proposed to favour the domestication of an animal species relate to its social/group structure, sexual behaviour, parent-offspring interaction, feeding behaviour, habitat choice and responses to new environments and humans (Price, 1984, 2002; Zeder, 2012b; see also Diamond, 2002). Natural selection can also play a role in the earliest stages of domestication, even before transition to captivity, when individuals of a wild population that are capable of approaching human-modified environments gain an adaptive advantage over other individuals (i.e., the commensal pathway to domestication; see below). Lastly, in captivity humans control access to the most fundamental resources for survival and reproduction, which means that many of the behaviours that are relevant for fitness in nature lose their adaptive significance (Price, 1984, 1999, 2002). According to this *relaxed selection* scenario, then, selection for certain traits, such as physical stamina, foraging and predator-avoiding strategies or cognitive abilities, will be relaxed in captive populations (e.g., Frank, 1980). Conversely, traits that were selected against in the natural population might increase their expression.

Overall, domestication involves the relaxation of selection pressures occurring in the natural environment and the occurrence of new selective pressures related to the association with humans (Zeder, 2015). Presumably, these multiple selective pressures act in concert and often it will be difficult to tease apart the relative contributions of relaxed selection, natural selection and artificial selection to changes in traits associated with domestication (Price, 2002; Zeder, 2015). Furthermore, domestication also generates phenotypic changes through correlated effects of selection, that is, through development of traits that were not targets of selection themselves but are correlated (genetically or functionally) with those directly selected (Per Jensen & Wright, 2014; Price, 2002; see domestication syndrome below). Finally, the environment can interact with the genome bringing about epigenetic alterations that can have transgenerational effects (Ahmad et al., 2020; Per Jensen & Wright, 2014).

The action of the aforementioned selective pressures will depend on the pathway to domestication followed by each species. Three general domestication pathways have been proposed, which vary in how they got started, the direction they have taken, and

their duration, namely, the commensal, the prey and the directed pathways (Zeder, 2012a, 2012b; see also Ahmad et al., 2020; Larson & Fuller, 2014 for reviews of the domestication history of several species). In the *commensal pathway*, animals approach human settlements to feed on their garbage or prey on other animals, thus initiating an association with humans. This initial commensal relationship, in which only the animal benefits, then evolves through the development of closer social or economic bonds between human and animal, and eventually turns into a domestic relationship. A typical example of a species that probably followed this route is the dog (Coppinger & Coppinger, 2001). The *prey pathway* was likely followed by most livestock species, such as sheep, goats, and cattle, which were initially hunted for their meat. In this scenario, humans might have developed game-management strategies to increase prey availability, which then led into herd-management strategies in which humans started to control animals' movement, feeding and reproduction across generations. The *directed pathway* probably came last once humans were familiar with other domestication pathways and deliberately initiated the process with the specific goal of obtaining a resource from a wild animal. The species that followed this pathway probably had less pre-adaptations for domestication and might include horses and donkeys, among others.

1.1.2. Selection for tameness and the domestication syndrome

Independently of the pathway followed, domestication always involves adaptation to a new, anthropogenic environment. An adaptation that is likely an universal feature of domestic animals, and that has been postulated as the most relevant effect of domestication on behaviour, is the decrease of emotional reactivity to changes in the environment or a reduction in stress responses (Herbeck & Gulevich, 2019; Price, 1999, 2002; Zeder, 2012b, 2012a). That is, a key element of domestication is the emergence of a less reactive temperament, which is seen as adaptive in an environment that is free of predators, but that can be stress-inducing given that it has limited opportunities for stimulation and involves frequent associations with conspecifics and humans (Price, 1999, 2002). This reduction in emotional reactivity is reflected in a decrease in responsiveness to fear-evoking stimuli and a diminished stress response, which is evident in different contexts, including intraspecific interactions, encounters with novel objects and environments and, importantly, interactions with humans (Price, 2002).

Adaptation to the new social environment might be crucial in the evolutionary process of domestication. Particularly, interaction with humans is a central selective factor in this process, fundamentally in the initial stages of domestication (L. N. Trut et al., 2004), since domestic animals must be able to tolerate proximity to and interactions with humans. Accordingly, one of the defining characteristics of domestic animals is increased tameness. The concept of *tameness* can vary depending on the author, though. For example, the term has been used to refer to the reluctance to avoid and/or the motivation to approach humans (Price, 2002), the “ability to interact with humans in a positive way” (Kukekova & Acland, 2006; pg. 516), and the ability to tolerate human close proximity or even handling “without triggering a fight-or-flight response” (Wilkins, 2020; pg. 144). Hence, tameness is related to emotional reactivity (Price, 2002), but while the former is specific to interaction with humans, the latter is a more general term. Also, although tameness and *docility* are often used interchangeably, the terms might not always be equivalent. For example, docility has been equated to general emotional reactivity (Frank, 1980), and it has also been used as a synonym of decreased aggressivity, separate from decreased reactivity and increased tameability (K. A. Lord et al., 2019). A. S. Wilkins (2017) regarded docility as a lack of fear and separated it from tameness, which was defined as the ability to be handled by humans.

Tameness can be operationally defined as the lack of fearful or aggressive responses towards human caretakers (Friederike Range & Marshall-Pescini, 2022a; Adam S. Wilkins et al., 2014). However, the concept of tameness has also been restricted to reduced fear of humans (Wright, 2015) (but has been equated to a reduction of fear in general too: Sánchez-Villagra et al., 2016), apparently separating it from aggression (even though, certainly, fear can lead to aggression). In other cases, it has been implied that there is a behavioural axis going from tameness to aggression, and the particular type of aggression that might be more relevant when discussing tameness is defensive (or reactive) aggression (Albert et al., 2008; Kukekova et al., 2008; Wrangham, 2019), which is presumably triggered by fear (Sánchez-Villagra & Van Schaik, 2019). “Decreased flight behaviour and increased sociality” have been considered “two trademarks of tameness” (Driscoll et al., 2009; pg. 9973) and a tame animal has been said to not only have a reduced flight distance or to tolerate human contact, but to also actively seek it (J. A. Serpell, 2021). In contrast, Wilkins et al. (2021) used the term docility as synonym of

tameness, referring to reduced fear and reactive aggression, and separated it from friendliness.

Overall, the concept of tameness commonly seems to involve a reduction of fear and aggression towards humans, and sometimes an increased motivation to seek human proximity and/or interaction. This has led some authors to differentiate between “tameness in the narrow sense”, which only involves reduced fear, and “tameness in the broad sense”, which incorporates social affiliation (Beckman et al., 2022), or between “passive” and “active” tameness (i.e., reluctance to avoid humans, and motivation to approach humans, respectively) (Goto et al., 2013; Nagayama et al., 2018). The term anthropophily has also been used to refer to this combination of reduced fear and aggression, and increased socialization with humans (Beckman et al., 2022). Changes in anxiety/fear, aggressive behaviour and affiliative behaviour might all underlie tameness (Herbeck & Gulevich, 2019). Hence, tameness might be seen as a complex phenotype comprised of multiple traits (Kukekova et al., 2011) that should be studied separately (Beckman et al., 2022; Goto et al., 2013).

Tameness can be genetically determined or can be acquired during one’s lifetime (Driscoll et al., 2009; Price, 2002). It is important to establish a separation between *domestication* and *taming*. In contrast to domestication, which implies genetic changes across generations (that is, over evolutionary time), taming is exclusively a learning process that takes place during an individual’s lifetime (Driscoll et al., 2009; Price, 1984, 1999, 2002). This process results in a reduction in the animal’s tendency to avoid humans and an increase in the tendency to approach (i.e., reduction in the social avoidance motivation and increase in the social approach motivation) (Price, 2002). This can be achieved through habituation, in which there is a repeated exposure to humans in a neutral context, or through positive associative conditioning, in which humans are associated with positive stimuli such as food (Price, 2002). This acquired tameness can make wild animals tolerant of humans, but this will not be genetically transmitted to their offspring.

Conversely, domestic animals have undergone a selective process that has led to a tameness that is genetically determined, or a “heritable predisposition toward human association” (Driscoll et al., 2009; pg. 9972). Tame behaviour is regarded as one of the defining features of what has been called the “domestic/domesticated phenotype” (Per Jensen, 2006; Per Jensen & Wright, 2014; Price, 2002). Intriguingly, apart from tameness, there are other phenotypic changes that commonly emerge in the domestication process

and are convergent in different species. That is, domestic animals possess a series of traits that separate them from their wild counterparts and that are shared between different domestic species, even if they are not closely related phylogenetically; an observation that was already made by Darwin (1868) himself. Wilkins et al. (2014) used the term “domestication syndrome” (DS) to dub the suite of morphological, physiological, and behavioural traits characteristic of domesticated mammals (although the concept was later extended to birds, and possibly even fish; Adam S. Wilkins et al., 2021), which, in addition to increased tameness, include changes in coat colour, ear and tail shape and craniofacial morphology, reductions in tooth and in brain size, alterations of neurotransmitters and stress hormones levels, disruption of the seasonality of sexual cycles, and retention of juvenile behaviours (see Sánchez-Villagra et al., 2016; Wilkins et al., 2014 and references therein).

Hare et al. (2012) classified the traits associated with the DS into four categories: physiological, anatomical, behavioural and cognitive. Here, I am mainly interested in the two latter categories. Regarding behavioural traits, the authors remarked not only the typical reduction in aggressiveness and increase in social tolerance, but also an increase in prosocial behaviours such as play and grooming. At the cognitive level, they pointed at some evidence of differences in problem-solving abilities between domestic animals and their wild counterparts, such as an increased sensitivity to human cues in domestic species.

1.1.3. The farm-fox experiment and other domestication experiments

Interestingly, selection for tameness is hypothesized to have played a major role in the development of the DS. In 1959, Belyaev initiated a domestication experiment with a population of silver foxes (a colour variation of the red fox, *Vulpes vulpes*) from fur farms in order to test his hypothesis that selection for tameability led to the emergence of similar patterns of morphological and physiological traits in domestic animals (L. Trut, 1999; L. Trut et al., 2009). In this experiment, the initial parental generation was composed of foxes that proceeded from different farm-bred populations, which were chosen because they lacked or displayed only a very weak aggressive or avoidance response in a behavioural test in which an experimenter approached and tried to open the

home cage. On successive generations, the tameness of the fox pups was examined in a series of monthly tests that were carried out since they were one month old until they were six or seven months old. In these tests, the experimenter offered food from their hand and tried to pet and handle the animal. The test was performed in two contexts: in a cage alone, and in an enclosure where the pup could move freely with other conspecifics. The fox pups only had short “time dosed” contacts with human beings and were not trained, with the intention of ensuring that the tameness resulted from genetic selection.

When they reached sexual maturity, the foxes were assigned to one of three classes according to their tameness score (L. Trut, 1999). Class III foxes fled from the experimenter or bit them when petted or handled. Foxes from class II tolerated physical contact (petting and handling) but didn’t display any emotionally friendly response to the experimenter. Finally, foxes belonging to class I behaved in a friendly manner toward the experimenter, which included tail-wagging and whining. Less than 10% of the tamest individuals of each generation were used as parents of the next generation (L. Trut et al., 2009). In the sixth generation, some foxes started displaying more intense dog-like behaviours, such as eagerly seeking human contact, whimpering to attract attention and licking the experimenters, even before they were one month old. These foxes were assigned to a new category, the “domestication elite”, whose proportion incremented progressively in the population, representing virtually the 100% of the population by 2005/2006 (L. Trut et al., 2009).

Crucially, in the foxes that were selectively bred based only on tameness correlated changes arose at the morphological, physiological and behavioural level, which were similar to those seen in domestic mammals (i.e., the domestication syndrome) (L. Trut et al., 2009). Domesticated foxes showed morphological traits such as piebald coat patterns, floppy ears, curly tails and, at a more advanced stage, shortened snout and upper jaw and widened skull. Regarding physiological changes, selection for tameness advanced sexual maturity and promoted sexual activity outside the breeding season. Moreover, the domesticated population presented neuroendocrine alterations, which included a reduction in the activity of the hypothalamus-pituitary-adrenal (HPA) axis and increased levels of serotonin in the brain, which have been hypothesized to account for reduced levels of stress, fear and aggressive responses (Popova, 2006; L. Trut et al., 2009; Adam S. Wilkins et al., 2014). At the developmental level, the onset of the fear response in tame fox pups was delayed, effectively resulting in a longer socialization window (L.

Trut et al., 2009; L. N. Trut et al., 2004). Remarkably, cognitive changes also surfaced, as domestic foxes outperformed farm-bred foxes in using human communicative cues (Hare et al., 2005).

Some of the findings of the farm-fox experiment have been confirmed and expanded in additional domestication experiments, in which an initial animal population is subjected to selection based on a behavioural trait and correlated changes in morphological, physiological and behavioural traits are examined. These studies support the hypothesis that selection against fearfulness or aggressiveness towards humans can lead to changes in other phenotypical traits, including modifications of neurotransmitter and hormone levels and alterations of behaviours related to fear in other contexts (e.g. neophobia) and to exploration, as well as intraspecific social behaviour (e.g., chickens: Agnvall et al., 2012, 2018; Gjøen & Jensen, 2022; rats: Albert et al., 2008; Naumenko et al., 1989; minks: Kulikov et al., 2016; but see section 1.1.5). There is suggestive evidence that phenotypical changes consistent with the DS also arise within few generations in populations of wild animals that experience nondeliberate selection for tameness (i.e., commensal pathway or self-domestication) (Geiger et al., 2018).

1.1.4. Hypotheses about the mechanisms underlying the domestication syndrome

Changes in the timing and rates of development (i.e., heterochrony) have been hypothesized to play an important role in domestication (e.g., Coppinger & Coppinger, 2001; L. N. Trut et al., 2004; but see Sánchez-Villagra et al., 2016). Particularly, neoteny, i.e., the retardation of development of somatic traits which, combined with an acceleration of sexual maturation, results in the retention of juvenile traits in adult individuals (i.e., paedomorphosis), has been invoked to explain linked traits of the DS. For example, morphological traits, such as floppy ears or shortened and widened face skulls, and behavioural traits, such as a reduction of fearfulness or an increase in positive responses to humans, have been associated with changes in the timing and rates of ontogenetic processes (L. Trut et al., 2009; L. N. Trut et al., 2004).

Belyaev proposed an explanation for why the alteration of developmental processes could be a consequence of selection for tame behaviour during domestication

(Belyaev, 1979). To put it simply, selection for behaviour likely leads to changes in neuroendocrine systems, which in turn play an important role in the control of ontogeny. The *destabilizing selection hypothesis* posits that selection for tameness provokes a destabilization of neuroendocrine systems controlling ontogenesis through changes in the regulation of genes (Belyaev, 1979; see also L. Trut et al., 2009; L. N. Trut et al., 2004; Wilkins, 2020). Relatedly, what has been called the *single genetic (regulatory) network hypothesis* speculates that the main genetic changes occur in upstream regulators, hence affecting numerous downstream systems (L. N. Trut et al., 2004).

Crockford (2004) saw the initial stage of domestication as an example of heterochronic speciation and discussed the potential implication of changes to thyroid hormones rhythms (THR). The *thyroid rhythm hypothesis* (or thyroid hormone hypothesis) essentially claims that selection for stress-tolerant individuals (e.g., less fearful) during domestication involves selection on THR variants or phenotypes and that, given the implication of THs in ontogenetic processes and multiple cellular functions, this could explain the appearance of a suite of morphological, physiological, and behavioural traits in domestic animals.

Wilkins and collaborators focus instead on the role of the neural crest cells (NCCs) in ontogenesis (Wilkins et al., 2014; see also Sánchez-Villagra et al., 2016). NCCs are stem cells that appear early in embryogenesis in the neural tube and that are directly and indirectly involved in the development of multiple cell and tissue types. The authors argue that the development of all DS traits is closely associated with NCCs and propose that a hypofunction of the neural crest, which is probably mediated by multiple genetic changes, could explain the origin of the diverse phenotypic changes of the DS (the *neural crest hypothesis*) (see A. S. Wilkins, 2017 for a comparison between this hypothesis and the thyroid rhythm hypothesis, especially from a genetic perspective, and an attempt to link both).

Recently, O'Rourke & Boeckx (2020) have proposed that selection for an attenuated stress response in domestic species (and in humans; see human self-domestication below) might have comprised modifications in glutamate receptors, which are involved in the regulation of the activation of the HPA axis (the *glutamate receptor hypothesis*), and could explain the reduction in reactive aggression. Moreover, these authors speculated as to how glutamatergic signalling could be related to broader DS traits and came up with two alternatives. First, selection for tameness could modify

glutamatergic signalling leading to a down-regulation of excitatory input to the HPA axis, which in turn would result in lowered glucocorticoid levels in domesticated females during pregnancy, which would eventually affect embryonic development by altering the expression of neural crest cells in different tissues. Alternatively, given that glutamatergic signalling genes are expressed in multiple cell types, including melanocytes, osteoblasts and chondrocytes, modifications of glutamatergic activity could have direct effects on morphological traits.

Finally, focusing on the underlying genetic mechanisms, the *cluster linkage hypothesis* (or *modularity hypothesis*) was presented as an alternative to the single genetic regulatory and the neural crest hypotheses, which are based on pleiotropic changes (Johnsson et al., 2014; Wright, 2015; Wright et al., 2020). In contrast, the modularity hypothesis considers linkage as the fundamental genetic mechanism involved in domestication. The authors suggest that the existence of linked genes surrounding a pleiotropic core could explain the findings of genetic analyses of domestic species (i.e., low occurrence of pleiotropy and presence of clusters of quantitative trait loci).

1.1.5. Critiques to the domestication syndrome hypothesis

However, several aspects of the DS have been questioned. Recently, Range & Marshall-Pescini (2022a) identified and summarised three main points that have been raised in discussions regarding the DS: 1) whether all domestic species present DS traits when compared to their wild counterparts, 2) whether selection for a single trait, and more specifically, selection for tameness, can explain the emergence of DS traits, and 3) whether the DS traits are indeed correlated with each other (i.e., whether they truly constitute a “syndrome”).

Regarding the first point, Lord et al. (2019), Range & Marshall-Pescini (2022a), and Sánchez-Villagra et al. (2016) provide a summary of findings regarding comparisons between wild and domestic forms which reveal inconsistencies in morphological, physiological and behavioural traits associated with the DS. It has been argued that there is not sufficient evidence of the existence of particular DS traits in many domestic species (K. A. Lord et al., 2019, 2020b; Sánchez-Villagra et al., 2016). However, Wright et al. (2020) argued that while many traits that have been attributed to the DS are species-

specific, there is considerable evidence of the existence of a universal DS, which involves a more restricted set of traits including changes in behaviour (tameness), in body and brain size and composition and in colour. Still, Lord et al. (2020) insisted on the scarce support for the DS, especially considering that the cross-species comparisons made might not be valid due to inappropriate choices of the populations taken as “domestic” and “wild” representatives.

With respect to the second point, the Russian farm-fox experiment is commonly cited as proof that selection for tameness can result in the appearance of DS traits. Nevertheless, conclusions derived from this experiment have not been without criticism (K. A. Lord et al., 2019; Sánchez-Villagra et al., 2016). Lord and collaborators questioned the relevance of its findings given that the foxes used in the domestication experiment proceeded from a captive population that had already experienced artificial selection and inbreeding (Lord et al., 2019; but see Zeder, 2020). In response, Trut and colleagues clarified some aspects regarding the population of origin of the foxes used in their project and concluded that their experiment is still a valid model of the historical domestication process (Lyudmila N. Trut et al., 2020; but see Lord et al., 2020b). On the other hand, Range & Marshall-Pescini (2022a) summarised findings from other domestication experiments with rats and red junglefowl and highlighted some results that are at odds with DS predictions (e.g., no differences between strains of red junglefowl in corticosterone response to physical restraint; Agnvall et al., 2015). In addition, they called attention to studies on a strain of farm foxes selected for aggression, which reveal that changes associated with the DS appeared in these foxes as well, and that similar neuro-morphological changes occur in tame and aggressive strains (Hecht et al., 2021; L. N. Trut et al., 2017). What’s more, these neuroanatomical changes are opposite to the expected effects of domestication (i.e., increased instead of decreased brain volume in both tame and aggressive strains compared to control farm-foxes). Hence, apparently selection for opposite behaviours (i.e., tameness and aggression) can bring about similar phenotypical changes, some of which have typically been considered characteristic of the DS.

The third point refers to the covariation of behavioural and morphological traits that constitute the DS. Following the DS hypothesis, one would expect that within a species morphological traits and behavioural traits associated with domestication would covary among themselves (morphology-morphology and behaviour-behaviour

correlations) and between each other (morphology-behaviour correlations). Again, Range & Marshall-Pescini (2022a) provide a short review of the findings so far.

Regarding correlation between morphological traits, apparently there is a lack of research and it was only recently that a study addressed covariation of domestication-related morphological traits among 78 dog breeds, failing to find any significant correlation between white pigmentation, floppy ears and curly tails (Hansen Wheat et al., 2020). However, as the authors remark, it should be acknowledged that the phenotypes of present-day dog breeds are a result of post-domestication selection pressures, that is, dogs' morphological traits might represent improvement traits and hence might not be too informative for the study of the initial stages of domestication (and consequently, for the DS).

With respect to covariation among behavioural traits, Hansen Wheat et al. (2019) examined the direction and strength of correlations between prosocial (sociability and playfulness) and reactive (fearfulness and aggression) behaviours in ancient and modern dog breeds. They found that the direction of behavioural correlations within prosocial (sociability with playfulness) and within reactive behaviours (fearfulness with aggression) was positive in both modern and ancient breeds, thus being consistent with the DS hypothesis. In contrast, correlations between prosocial and reactive behaviours, which are hypothesized to be negative in the DS hypothesis, were only significant in ancient breeds, which showed exaggerated effect sizes when compared to modern breeds.

Finally, concerning morphology-behaviour correlations, Hansen Wheat et al. (2020) also examined the relationship between morphological traits and the previously mentioned behavioural correlations among dog breeds. They discovered that the presence/absence of domestication-related morphological traits (i.e., white pigmentation, floppy ears and curly tail) and the number of morphological traits present in a dog breed did not predict the strength of the behavioural correlations. On the other hand, an association between depigmentation and tameness has been found in minks and sables (Trapezov et al., 2008). In any case, the covariation between morphological and behavioural traits predicted by the DS warrants further research, and one should bear in mind that certain morphological traits might be the result of direct selection during posterior stages of domestication.

1.1.6. Self-domestication

Self-domestication is a concept that can have a range of meanings. On the one hand, taken literally, the term refers to a domestication process directed towards the self, that is, a process in which species domesticate themselves. Hence, self-domestication can be linked to the commensal pathway of domestication (e.g., Morey & Jeger, 2015), in which it is the animal that initiates the process by associating with humans (Zeder, 2012a). On the other hand, if domestication is equated with an evolutionary process of selection for reduced aggression that doesn't require association with humans, and its phenotypical outcomes (i.e., the DS), the concept can be applied to wild species as well (Hare et al., 2012; Wrangham, 2021; but see Morey & Jeger, 2015 for an opposing view). Thus, a wild species that has experienced natural selection against aggression and that possesses traits typical of the DS can be said to have gone through a self-domestication process.

This “outcomes view of domestication” (Thomas & Kirby, 2018) allows, or at least facilitates, the application of the notion of self-domestication to the human species (but see Losey, 2022 for an opposing view). Then, “humans can be considered domesticated to the extent that they: (1) share in the domestic phenotype; and (2) that those phenotypic similarities have arisen in response to similar evolutionary circumstances and selective pressures, and are underpinned by similar biological mechanisms” (Thomas & Kirby, 2018; pg. 16). The idea that the human species has experienced a self-domestication process has a long history (for reviews see Brüne, 2007; Leach, 2003; Sánchez-Villagra & Van Schaik, 2019; Wrangham, 2021) and continues to attract scientific interest (e.g., collection of papers in Benítez-Burraco et al., 2020), although the specific implications of this proposal vary between researchers. Here, I will focus on Hare's *human self-domestication hypothesis (HSD)* (Hare, 2017).

The HSD is built upon the notion that selection against aggression in domestic species drove the emergence of a set of correlated traits as a by-product (i.e., the DS) and aims to extend this idea to wild species (Hare et al., 2012). Hence, self-domestication in this context refers to the process of natural selection for reduced aggression and increased social tolerance within a wild species that triggers changes in a suite of traits at the morphological, physiological, behavioural and psychological levels that are similar to those observed in the so-called DS of domesticated species (named the “self-

domestication syndrome” by Wrangham, 2021). Therefore, the hypothesis suggests that phenotypic differences between closely related wild species that differ in their aggression and tolerance levels could be explained by a self-domestication process. For example, the authors highlighted that bonobos, when compared to chimpanzees, present analogous phenotypical changes to those seen in domestic species, and suggested that these arose due to a process of selection against intraspecific aggression (i.e., self-domestication) (Hare et al., 2012; see also Wrangham, 2021).

Hare then extended this conceptualization of self-domestication to humans (Hare, 2017). The HSD proposes that during late stages of human evolution there was a selection for intragroup prosociality (i.e., positive social interactions) and against aggression, that led to the emergence of DS traits in our species (Hare, 2017; see also Sánchez-Villagra & Van Schaik, 2019; Wrangham, 2019, 2021). The HSD is closely linked to the *emotional reactivity hypothesis* (Hare & Tomasello, 2005b), which suggests that a decrease in emotional reactivity led to an increase in social tolerance which in turn enabled the appearance of complex levels of cooperative communication or social cognition in humans (see below for the application of this hypothesis in the context of dog domestication). Yet, the HSD extends this proposal and claims that this more flexible social tolerance in humans is not only a result of reduced emotional reactivity but also of a substantial increase in self-control or inhibition, which is a unique feature of human self-domestication (Hare, 2017). It is purported as well that reduced reactivity increases the reward for social interactions.

Therefore, the HSD establishes a parallel between human evolution and domestication through the proposal that both humans and domestic species experienced a selection for prosociality (understood as positive social interactions as opposed to antisocial interactions), that resulted in the manifestation of a shared set of anatomical, physiological, behavioural and cognitive traits as a by-product (i.e., the DS). Unsurprisingly, this proposal is not accepted by some scholars. For example, Shilton et al. (2020) believe that a hypothesis focusing solely on selection against aggression and for prosociality is insufficient as an explanatory model of human social evolution. Instead, they emphasize selection for emotional control and plasticity, which is not necessarily linked to a general decrease in aggression. Moreover, they highlight differences between humans and domestic animals, such as the higher complexity of human social structures

and the increase in brain size during most of human evolution, and advocate for comparisons with other highly social mammals instead.

1.1.7. Dog domestication

Dogs are believed to be the first domesticated species, although the history of their domestication is unclear, with aspects such as its geographical location and temporal frame, and whether it involved a single or multiple events and wolf populations still being debated (e.g., Bergström et al., 2020, 2022; Botigué et al., 2017; Frantz et al., 2016; Larson et al., 2012; Morey & Jeger, 2015; Ovodov et al., 2011; Thalmann et al., 2013; vonHoldt et al., 2010). There are two main hypotheses regarding how dog domestication got started (domestication scenarios). According to the *commensal scavenger hypothesis* (commonly attributed to Coppinger & Coppinger, 2001; but see Serpell, 2021), dogs' ancestors approached human groups, presumably because they could obtain valuable food resources in the human niche. Hence, those individuals that had a temperament that allowed them to be in proximity to humans (i.e., those less fearful and aggressive) gained a selective advantage over the rest. Over time, the association with humans became stronger, probably once humans realized the benefits they could reap from this relationship, eventually leading to direct selection. This hypothesis represents a particular case of Zeder's commensal pathway (Zeder, 2012a, 2012b), as mentioned above, and has also been referred to as the self-domestication model/hypothesis/scenario (e.g., Germonpré et al., 2021; Losey, 2022; Sarah Marshall-Pescini, Cafazzo, et al., 2017).

Although this view is currently mainstream, it has also been questioned (e.g., see Serpell, 2021 for a critical review) and interest for an alternative hypothesis has been reignited recently: the *cross-species adoption hypothesis* (commonly attributed to Clutton-Brock, 1994; but see Serpell, 2021), also dubbed pet-keeping hypothesis, wolf pup-adoption model, human-initiated model or human-selection scenario (e.g., Germonpré et al., 2021; Losey, 2022; Sarah Marshall-Pescini, Cafazzo, et al., 2017; Serpell, 2021). In contrast with the previous hypothesis, in this model humans are the initiators of the domestication process, through adoption of pups of ancient wolves. These pups would be hand-reared, socialized and incorporated into human communities. Those

individuals that possessed traits that made them better adapted to domestic life (e.g., less aggressive and more sociable) would have been favoured.

1.1.7.1. Dog domestication hypotheses

Apart from the origins of dogs, the selection pressures that dogs experienced during the domestication process and its consequences at the behavioural and cognitive levels have gathered substantial scientific attention. Numerous hypotheses have been formulated regarding the selective pressures that have shaped dogs, which likely include new natural selective pressures associated with the human environment, the relaxation of selective pressures associated with life in the wild, and artificial selection for human-preferred traits. These hypotheses speculate about the crucial behavioural and cognitive changes that dogs went through during domestication and that set them apart from wolves. Table 1.1 provides a summary of the most prominent hypotheses, some of which are not necessarily mutually exclusive. Here we will present a brief overview of the current evidence for and against some of them, focusing on aspects related to dog-human interaction (see Range & Marshall-Pescini; 2022a for a thorough review).

Comparing dogs to their closest wild-living relatives, wolves, can give us an idea of the changes that the domestication process brought about, assuming that present-day wolves are representative of the common ancestor of dogs and wolves. It is important to bear in mind that dogs and wolves have to be exposed to similar developmental contexts and learning opportunities to reach valid conclusions regarding the role of domestication in wolf-dog differences (e.g. Ádám Miklósi, 2007; Range & Virányi, 2015; Udell et al., 2012). This hasn't been the case in many studies, and so their results should be interpreted with caution.

Table 1.1.*Dog domestication hypotheses*

Hypothesis	Statement	Predictions	Source
Human socialization	Selection against development of fear resulted in an extended sensitive period that facilitates socialization to humans	The development of fear should occur later in dogs than in wolves, hence dogs should possess a longer sensitive period than wolves and should be easier to socialize to humans	Scott & Fuller (1965)
Two behavioural tendencies	Domestication reduced flight tendencies and increased motivation to seek social contact with humans	Dogs should show a reduced tendency to escape from and an increased tendency to approach humans compared to wolves	Zimen (1987)
Information processing	Domestication relaxed selection pressures for cognitive complexity and favoured tractability instead	Wolves should outperform dogs on problem-solving tasks, while dogs should surpass wolves in training tasks	Frank (1980, 2011); Frank & Frank (1982)
Selection for communication	Domestication led to the emergence of human-like socio-cognitive abilities. The ability to read human signals was a direct target of selection.	Dogs should possess better skills for communication with humans than wolves regardless of their experience with humans	Hare et al. (2002)
Emotional reactivity	Selection against fear of and aggression towards, and in favour of social contact with humans (i.e., selection for tameness or reduced emotional reactivity) incidentally led to an increased ability to read human social-communicative behaviours.	Dogs should show less fear of and aggression towards humans, and higher human-oriented social motivation than wolves Dogs should possess better skills for communication with humans than wolves regardless of their experience with humans Reduced emotional reactivity should be linked with increased socio-cognitive skills	Hare & Tomasello, (2005b)

Table 1.1 (continued)

Hypothesis	Statement	Predictions	Source
Emotional reactivity	In its second version: selection for reduced aggression not only in the interspecific context, but also at the intraspecific level.	In its second version: dogs should display less intense aggressive behaviour in inter- and intra-group interactions than wolves	Second version: Hare et al. (2012)
Attachment	Dogs might have experienced selective breeding for dependency and attachment to humans. Dogs acquired a capacity for attachment to humans during domestication. This attachment system is functionally analogous to the human-infant attachment and is the basis for the development of dog-human social behaviour	Dogs, but not wolves, should display behavioural patterns consistent with attachment to humans	Topál et al. (2005)
Cooperation and attention	Dogs were selected for their cooperative ability and enduring attention towards humans	Dogs should be more cooperative with and attentive towards humans than wolves	Gácsi, McGreevy, et al. (2009)
Synergistic	Positive feedback between evolutionary and ontogenetic processes resulted in dogs' tendency to gaze at the human face, which provides the basis for complex forms of dog-human communication. Selection pressures acted on dogs' emotionality and reactivity, leading to a higher aggression control and action inhibition, and on their socialization system, resulting in a heightened sensitivity to socialization with humans. Dogs might present an epigenetically enhanced sensitivity to human communicative signals.	Dogs should show a higher tendency to gaze at the human face than wolves Dogs should show higher aggression control and action inhibition, and should be more sensitive to socialization with humans than wolves Dogs should be more sensitive to human communicative signals than wolves	Gácsi, Györi, et al. (2009)

Table 1.1 (continued)

Hypothesis	Statement	Predictions	Source
Dog Behaviour Complex	Dog evolution is determined by the synergistic effect of changes in a wide range of social behaviours (the Dog Behaviour Complex) that occurred in parallel. This Behaviour Complex includes behaviours that presumably contribute to dogs' success in the human social niche, such as attachment, inequity aversion, emotional synchronization, social learning, selective responsiveness to human attention, initialization of eye contact and use of human directional gestures.	Dogs should display higher levels of human-directed social behaviours belonging to the Dog Behaviour Complex than wolves	Topál et al. (2009)
Two Stage	Dogs' sensitivity to human actions is a consequence of 1) socialization to humans during the sensitive period of development, and 2) learning of the association between specific human stimuli and reinforcements	Dogs and wolves should perform equally on tasks requiring the use of human stimuli if 1) exposure during their sensitive period allowed them to accept humans as social companions and 2) they had opportunities to learn associations between these stimuli and certain behavioural outcomes	Udell et al. (2010b)
Evolutionary social competence	Domestication involved an initial unconscious selection for human-like evolutionary social competence in ancestral wolves and a posterior direct selection on dog social behaviours	Dogs should show a higher interspecific social competence than wolves	Ádám Miklósi & Topál (2013)
Canine cooperation	Dogs inherited from wolves the social tolerance and attentiveness necessary for successful dog-human cooperation	Dogs should be as cooperative with and attentive towards humans as wolves are with each other	Friederike Range et al. (2015)

Table 1.1 (continued)

Hypothesis	Statement	Predictions	Source
Dependence	Dogs have a hypersensitivity or dependence on human social cues that interferes with their independent problem-solving behaviour and might be a conditioned response	Dogs should be more dependent on humans or less independent when solving problems than wolves	Udell (2015)
Hypersociability	Domestication led to an exaggerated motivation to seek social contact (i.e., exaggerated gregariousness or hypersociability). Individuals with hypersocial tendencies were selectively bred during the domestication process. Dogs' hypersocial behaviour is expected in interactions with any bonded partner, not only humans.	In interaction with bonded partners, dogs should display higher levels of sociability-related behaviours, such as proximity-seeking and gazing, than wolves	Bentosela et al. (2016); vonHoldt et al. (2017)
Social ecology	Importance of the dissimilarities in feeding ecology and social organization of wolves and free-ranging dogs as explanations for wolf-dog behavioural and cognitive differences	At the intraspecific level, dogs should have a lower social tolerance and inferior social learning and cooperative abilities than wolves Dogs should be less persistent, risk-prone and neophobic than wolves	Sarah Marshall-Pescini, Cafazzo, et al. (2017)
Deferential behaviour	After an initial selection for reduced fear of humans, dogs were selected for increased deference or submissive inclinations, which enabled successful cooperation with humans	Dogs should be more likely to avoid conflicts with humans and follow their lead in cooperative interactions than wolves	Friederike Range et al. (2019); Friederike Range & Marshall-Pescini (2022a)

As mentioned earlier, changes in the timing of early developmental processes (i.e., heterochrony) are thought to have played an important role during domestication, and hence are believed to be one of the underlying causes of the behavioural differences between adult wolves and dogs. These species differ in the duration of their socialization period (but see Lord, 2013), which is a sensitive period in development that is important for species identification and affects the choice of future social partners (e.g., Fox, 1969). The socialization period ends when fear inhibits the exploration of novelty (Scott & Fuller, 1965). Since dogs might be socialized until 12-14 weeks or even longer, while wolves show strong fear of strangers already by 6 weeks of age (J. Serpell et al., 2017), it is believed that domestication might have delayed the onset of the fear response in dogs. Indeed, the farm-fox experiment demonstrated that selection for tameness can slow down the development of the fear response, delaying its appearance (L. Trut et al., 2009). However, recent findings suggest that wolf-dog differences are due to a loss of sensitivity toward novelty with age in dogs, rather than a shift in the appearance of the fear response (Hansen Wheat, van der Bijl, et al., 2019). Species differences in fear expression were not found until 18 weeks of age, when they emerged due to a progressive reduction in dogs' fear response (Hansen Wheat, van der Bijl, et al., 2019; Sarah Marshall-Pescini, Virányi, et al., 2017).

It is known that dogs are easier to socialize to humans than wolves (in line with e.g., *human socialization hypothesis*, *synergistic hypothesis*, Table 1.1). While dog pups can form interspecific bonds if they are exposed to humans before 7-8 weeks of age, wolf pups need to be hand-reared from at least 2-3 weeks of age to create reliable social bonds with humans (J. Serpell et al., 2017). Several hypotheses propose that dogs were selected for an increased tendency or motivation to seek social interaction with humans and that they display more human-directed sociability-related behaviours (e.g., proximity and contact-seeking, gazing) than wolves (e.g., *two behavioural tendencies hypothesis*, *emotional reactivity hypothesis*, *synergistic hypothesis*, *Dog Behaviour Complex hypothesis*, *hypersociability hypothesis*). In contrast to wolf pups, dog pups seem to express a preference towards humans over conspecifics (Frank & Frank, 1982; Gácsi et al., 2005). Moreover, dog pups establish eye contact faster and display more human-directed communicative behaviours than wolves (Gácsi et al., 2005; Gácsi, Györi, et al., 2009). Compared to adult wolves, dogs have also been found to gaze longer at human's faces, approach humans faster and remain in proximity and in contact for longer, seeking

out proximity even when the human is ignoring them (Bentosela et al., 2016; Lazzaroni, Range, et al., 2020; vonHoldt et al., 2017). Importantly, these species differences in sociability-related behaviours directed towards humans have been found even when controlling for life experiences.

It has been highlighted that wolves' individual differences in sociability could be the basis on which selection acted during domestication, and that dogs' smaller variability could support the notion that they have been subjected to selection for high sociability (Lazzaroni, Range, et al., 2020; Wirobski et al., 2021). Selection requires heritable traits and findings from several studies suggest that variation in sociability towards humans has an important genetic component (M. E. Persson et al., 2015; A.-S. Sundman et al., 2016; Van Der Waaij et al., 2008). Interestingly, apparently the potential genetic basis for dogs' hypersociability are structural variants in genes associated with Williams-Beuren syndrome (WBS) in humans, a neurodevelopmental disorder characterized by hypersocial behaviour (vonHoldt et al., 2017).

On the other hand, studies addressing the relative reinforcer efficacy of social interaction and food, as well as the animals' preference for a contact provider over a food provider, have found no differences between wolves and dogs (Feuerbacher & Wynne, 2012; Lazzaroni, Range, et al., 2020). Thus, although wolf-dog comparative studies have demonstrated that dogs show more sociability-related behaviours towards humans, some researchers have argued that it is unclear what the motivation to interact with humans might be (Lazzaroni, Range, et al., 2020; Friederike Range & Marshall-Pescini, 2022a). It is worth mentioning that Scott & Fuller (1965) cited several studies that seem to refute the idea that dogs are motivated to interact with humans merely because they provide them with food. In addition, dogs did spend more time in contact with a human that only provided petting than wolves (Lazzaroni, Range, et al., 2020).

In any case, it has been speculated that wolf-dog differences in sociability-related behaviours might not be driven by differences in social motivation per se, and that they might be related to compliance instead (*deferential behaviour hypothesis*; Friederike Range et al., 2019; Friederike Range & Marshall-Pescini, 2022a). This hypothesis was based on observations of dog-wolf differences in their conflict management strategies at the intraspecific level, as well as on their behaviour in cooperative interactions with humans. Particularly, in intraspecific contexts, subordinate dogs usually avoid approaching dominant dogs in presence of a food resource, and they don't try to reconcile

after a conflict occurs, but keep their distance instead (Dale et al., 2017; Lazzaroni et al., 2018; Friederike Range et al., 2015). Moreover, when cooperating with humans, dogs were more likely to wait for the human to take the initiative and then follow their lead (Friederike Range, Marshall-Pescini, et al., 2019). It has also been observed that dogs show more greeting and submissive behaviours towards humans than wolves, and that even if they might find physical contact with certain humans stressful (based on cortisol increases and self-directed behaviours such as lips licking or yawning), they don't avoid the interaction like wolves do (Friederike Range & Marshall-Pescini, 2022a; Wirobski et al., 2021). Some authors have placed the emphasis on the capacity for attachment to humans and have proposed that it was acquired during domestication (e.g., *attachment hypothesis*, *Dog Behaviour Complex hypothesis*, Table 1.1). The Strange Situation Test (SST), which was initially developed to study attachment relationships in human infants (Ainsworth & Bell, 1970), has been used to investigate the formation of attachment bonds with humans in dogs and wolves. Although initial findings suggested that wolves don't form attachment bonds with their caregivers (Topál et al., 2005), posterior studies showed that wolves do display attachment-like behaviours and distinctive affiliation and affinity towards their caregivers (Hall et al., 2015; Rita Lenkei et al., 2020; Ujfalussy et al., 2017; Wheat et al., 2020). These results might imply that rather than providing dogs with the ability to form attachments to humans, domestication could have changed the ease with which these bonds are formed and the conditions that elicit attachment behaviours (Hall et al., 2015).

Many domestication hypotheses have emerged to provide an explanation for dogs' socio-cognitive abilities in their interactions with humans, especially their ability to read human communicative gestures (see also sections 1.4 and 1.5.2). Some researchers posit that dogs acquired these skills during domestication, either as a result of direct selection (*selection for communication hypothesis*, *evolutionary social competence hypothesis*) or as a by-product (*emotional reactivity hypothesis*, Table 1.1). Hence, dogs are expected to outperform wolves in tasks assessing their ability to follow human cues. Other authors have emphasized the role that both phylogeny and ontogeny have on an animal's performance on human-guided tasks (*synergistic hypothesis*, *Two Stage hypothesis*; see also Udell & Wynne, 2008, 2010). According to this view, domestication is not sufficient, nor necessary for a successful performance on these tasks, which depends instead on the acceptance of humans as social partners and associative learning. If dogs' skills are

subordinate to their exposure to human communicative behaviours, one would expect an improvement during the lifetime and differences between dog populations differing in their degrees of interaction with humans. The debate regarding the relative importance of domestication and life experiences in the development of dogs' social behaviour towards humans permeates the literature (e.g., Hare et al., 2010 vs Udell et al., 2008; Hare & Tomasello, 2005 vs Á. Miklósi & Topál, 2005; Riedel et al., 2008 vs Wynne et al., 2008).

Initial findings supported the notion that dogs' socio-cognitive skills were superior to those of wolves (e.g., Agnetta et al., 2000; Hare, 2002; Ádám Miklósi et al., 2003), but later studies cast doubts on these claims (Gácsi, Györi, et al., 2009; Lampe et al., 2017; Udell, Dorey, et al., 2008; Udell et al., 2012). In any case, it has been proved that domestication is not necessary to successfully follow human communicative gestures, since non-domestic species, including wolves, can perform above chance level in these tasks (for a review see Krause et al., 2018). It has also been demonstrated that domestication is not sufficient, with some dog populations, such as shelter dogs and kennel-reared dogs, failing to use human communicative cues (D'Aniello et al., 2017; Lazarowski & Dorman, 2015; Osborne & Mulcahy, 2019; Udell, Dorey, et al., 2008; for reviews see Duranton & Gaunet, 2016b; Jarvis & Hall, 2020). Yet, there is also evidence that dogs can follow human gestures from a young age before receiving substantial experience with humans and with little signs of learning (Bray et al., 2020, 2021; but see Dorey et al., 2010; Wynne et al., 2008). Overall, these results seem to suggest that although domestication is not necessary nor sufficient for the emergence of these socio-cognitive abilities, it might have provided dogs with a biological bias or predisposition to attend to human communicative cues, facilitating the early emergence of these skills.

1.2. SOCIAL MOTIVATION

As manifested in the previous section, numerous traits have been hypothesized to have been affected in the domestication process. One element that has emerged repeatedly in the domestication hypotheses, apart from fearfulness, is dogs' social motivation towards humans, especially if one views social motivation as a multifaceted construct or a construct with multiple possible behavioural manifestations (see next sections). Zimen (1987) explicitly proposed that domestication might have affected dogs' motivation to

seek social contact with humans (*two behavioural tendencies hypothesis*, Table 1.1). The *emotional reactivity hypothesis* envisages not only a selection against fear and aggression but also in favour of social contact with humans. Some authors make reference to dogs' increased tendency to gaze towards humans in different contexts (e.g., *cooperation and attention hypothesis*, *synergistic hypothesis*, Table 1.1), a behaviour that likely reflects an aspect of social motivation. The *Dog Behaviour Complex* proposed by Topál and collaborators (2009) included a set of social behaviours, such as synchronization, which fit in the social motivation construct. Clearly, social motivation is a central aspect of the *hypersociability hypothesis* (Bentosela et al., 2016; vonHoldt et al., 2017). Frank (1980) hypothesized that domestic animals are selected for tractability or controllability, which could potentially be related to conformity, which in turn can be regarded as a manifestation of social motivation.

If selection for tameness is essential in domestication and tameness is seen as a phenotype composed of multiple traits, including not only low fear and aggression but high social motivation, the study of this construct is relevant to the topic of domestication in general. It has been proposed that fearfulness, aggression, sociability and playfulness are the key behavioural traits implicated in the DS (Hansen Wheat et al., 2018, 2019). Regarding dog domestication, it seems plausible that, apart from their fear towards humans, dogs' social tendencies were also altered during domestication (Zimen, 1987).

In this section I will briefly review different conceptualizations of social motivation in the human literature and present the model we adopted in our study and how it can be applied to dogs for studying their human-directed social motivation. To close the section, I will consider empirical evidence of associations between behaviours that are regarded as manifestations of social motivation in dogs.

1.2.1. The construct of social motivation in the human literature

Social motivation has been recognized as an important element in the evolution and development of human social behaviour. There is evidence suggesting that in our species social motivation, in its broadest sense, is exceptionally strong. For example, from a young age we prefer to perform joint tasks instead of individual tasks, in contrast to other great apes (Rekers et al., 2011). Social motivation has been proposed as an

explanation for the early emergence of prosociality in humans, especially for helping behaviours (Carpendale et al., 2015; Over, 2016; Paulus, 2014; Pletti et al., 2017; Rheingold, 1982). In this context, various definitions and terms have been used, and sometimes researchers have focused on different aspects of social motivation or have worked with different social motivation-related concepts.

Carpendale et al. (2015) talk about “young children more-general tendency toward social engagement and interest in being involved in the activity of adults” (p. 357). Likewise, Dahl & Paulus (2019) mention a “social preference for interacting with others” or “social interest in joint activities” as a possible explanation for early prosocial behaviours (pg.11). Hammond & Drummond (2019) focus on the concept of “social interest”, which for them is the “interest in the activities of others” (p. 1882). In their review, Eisenberg et al. (2016) present “social relatedness” as one of the possible motives behind children’s prosocial actions, and they describe it as the “need for relatedness or the pleasure of social interaction” (pg. 1672). Sierksma & Shutts (2021) mention “children’s motivation to spend time with others and affiliate” (p. 3). Similarly, the term “affiliative motives” has been used interchangeably with “social motives” (Giner Torr ns & K rtner, 2019; Paulus, 2018). Finally, some authors use the terms “social motives” or “social motivation” when referring to the motivation or desire to interact or engage in joint activities and affiliate with others, often highlighting the pleasure or joy derived from these interactions (Eisenberg, 2020; Giner Torr ns & K rtner, 2019; Paulus, 2014, 2018; Pletti et al., 2017). As can be seen, even if various definitions and terms have been used, there is a substantial overlap of meanings between them.

Beyond the labels and definitions discussed above, some of the researchers interested in social motivation or related concepts have explained more thoroughly the constructs they present in their conceptual frameworks. Over (2016), for example, works with the conceptualization of the need to belong of Baumeister & Leary (1995), which refers not only to the motivation to engage in social interactions, but also emphasizes that these interactions must be the basis for the formation of long-term social bonds, and this is mainly what gives them value. Furthermore, as its name suggests, it is not only a desire but a need, meaning that if it is not satisfied it causes distress and, if this deficiency is maintained in the long term, it has negative effects on the welfare and health of the individual (Baumeister & Leary, 1995).

Tomasello et al. (2005) focus instead on the motivation to share psychological states. In particular, these authors propose that the crucial difference between humans and other species is that the former possess the motivation to share emotions, experiences and activities with other individuals, and the cognitive ability to form a shared intentionality.

On the other hand, Godman (2013) considers that social motivations are a group of emotional and affective factors, involved specifically in social contexts that include other people, and that make social experiences intrinsically rewarding. The social motivation hypothesis by Godman et al. (2014) suggests that there is a psychological disposition that makes us orient toward affiliative stimuli, resulting in a social reward and allowing the formation of social bonds. The authors establish a connection between this hypothesis and the social motivation theory proposed by Chevallier et al. (2012) in the context of autism, a conceptualization that inspired the conceptual framework of social motivation of our own study.

Chevallier et al. (2012) described social motivation at the proximate and at the ultimate level. At the ultimate level, social motivation can be seen as an evolutionary adaptation that increases individuals' fitness in collaborative environments. Furthermore, this motivation for social affiliation is distinct from other types of social motivation, such as those associated with sexual, parental and dominance relationships. At the proximate level, the authors defined social motivation as “a set of psychological dispositions and biological mechanisms biasing the individual to preferentially orient to the social world (social orienting), to seek and take pleasure in social interactions (social reward), and to work to foster and maintain social bonds (social maintaining)” (Chevallier et al., 2012, p. 232). They thus proposed that there are three types of behavioural manifestations of humans' social interest: 1) social orienting, 2) social reward, and 3) social maintaining. The authors also suggested potential neurological and endocrinological mechanisms underlying social motivation. In our research project we propose that this model can serve as a theoretical framework for the study of social motivation towards humans in the domestic dog (see also Galambos et al., 2021 and Mulholland et al., 2021 for application of this model in dogs and chimpanzees, respectively).

1.2.2. Social motivation in the dog

In this section I will describe the three categories devised by Chevallier et al. (2012), present canine social behaviours that might fit in each of them and review the corresponding literature (see also József Topál et al., 2019). Although in general dogs are a highly social species especially motivated to interact with humans, probably due to the domestication process, as we will see, there is important individual variation in dogs' social interest that warrants further research.

1.2.2.1. *Social orienting*

Social orienting refers to attentional priority granted to social signals or objects with social importance (Chevallier et al., 2012). For example, core deficits seen in this category in infants with autism include impaired orienting to visual or auditory social stimuli, infrequent orienting to one's own name and diminished eye contact. In this regard, Kovács et al. (2016) provided the first evidence that dogs show spontaneous positive attentional bias towards point-light displays representing biological motion over non-biological control stimuli. Although there have been mixed results when comparing looking times towards displays depicting humans or dogs in frontal or lateral orientation to control stimuli (Delanoëje et al., 2020; Eatherington et al., 2019; Ishikawa et al., 2018), there is evidence supporting the sensitivity of dogs towards biological motion.

A method that allows for a more precise analysis of the orientation of attention is eye-tracking. The majority of canine eye-tracking studies have focused on dogs' visual processing of human or dog faces (e.g., discrimination of familiar individuals, recognition of emotions...), without making a direct comparison between the attention allocated to social and non-social stimuli. Results of a pioneer study on the use of eye-tracking in dogs suggest that dogs might indeed show a preference for social categories, since their fixation time was longer for images of dogs and humans than for images of toys and alphabetic characters (Somppi et al., 2011). However, the sample size was small ($n = 6$), and the findings are contradicted by a previous study, in which no difference in viewing time across image categories (dog faces, human faces and objects) was found (Racca et al.,

2010). Thus, evidence for dogs' attentional bias towards social stimuli using eye-tracking methods is rather limited.

Behavioural studies have also investigated orientation towards social stimuli in dogs. A recent study found that a social stimulus (a videoclip of a man's face) was more distracting for dogs than a non-social stimulus (a videoclip of a book cover) when presented simultaneously with a target stimulus during a touchscreen task (Galambos et al., 2021). When examining the first trials with the social and non-social stimuli, the authors found that the latency to execute the task (touch the target stimulus on the screen) was longer in the social distractor trials. Other studies have revealed that dogs show increased sustained attention toward a social stimulus (human) compared to a non-social stimulus (toy) (Chapagain et al., 2017; Wallis et al., 2014), and were found to orient more frequently towards meaningful auditory stimuli (which included a barking dog, a meowing cat and a human command) compared to a neutral word (Reinholz-Trojan et al., 2012).

In fact, there is ample evidence that dogs pay attention to human social signals such as pointing gestures, gaze, facial expressions and verbal cues (Albuquerque et al., 2016; Topál et al., 2014). Research, however, has not only investigated dogs' allocation of attention to human social signals, it has also examined their use. Social signals provided by a human, such as gaze, have proven to be more salient and effective than non-social cues for dogs solving object choice tasks (OCTs) (Agnetta et al., 2000; Udell, Giglio, et al., 2008). Eye contact with humans and use of pointing gestures have been extensively studied in dogs (reviewed in Topál, Kis, & Oláh, 2014). Dogs have a spontaneous tendency to gaze at a human's face from a young age, in contrast to wolves (e.g., Gácsi et al., 2009). Nevertheless, individual variation and breed differences in tendency to make eye contact with humans have been shown (Jakovcevic et al., 2010; Sarah Marshall-Pescini et al., 2009), as well as in the ability to use pointing gestures (e.g., Virányi et al., 2008; Wobber, Hare, Koler-Matznick, Wrangham, & Tomasello, 2009).

Gazing behaviour towards humans has often been interpreted as a help-requesting behaviour (but see Lazzaroni et al., 2020; Sarah Marshall-Pescini et al., 2017; Udell, 2015). Dogs resort to us when confronted with problems they are unable to solve (e.g., Carballo, Cavalli, et al., 2020; Gaunet, 2008; Heberlein et al., 2016; Sarah Marshall-Pescini et al., 2009; Á. Miklósi et al., 2000; Ádám Miklósi et al., 2003; Passalacqua et al., 2011; Sommese et al., 2019). In this context, the proportion of time dogs spend

looking at a human instead of at the apparatus they are trying to solve, has been taken as a measure of attentional bias to social stimuli (vonHoldt et al., 2017).

All in all, although the use of certain methods has led to mixed findings, overall dogs show an attentional bias towards human-related social stimuli or signals. Interestingly, though, several studies point to the existence of individual differences in social orienting, that might be related to particular experiences or personality traits.

1.2.2.2. Social reward

An additional manifestation of social motivation is to find social interactions rewarding. Potential deficits in this component, seen in individuals with autism, include a diminished response to social rewards (e.g., verbal praise) and reduced preference for collaborative activities. Moreover, it has been proposed that if social interactions have intrinsic motivational value, the “overjustification effect” might be seen (i.e., extrinsic incentives might weaken intrinsically motivated social behaviours) (Chevallier et al., 2012).

Regarding dogs’ responses to social rewards, Feuerbacher & Wynne (2014) found that, in general, pet dogs preferred food to petting (i.e., a social reward), but group and individual differences were noticeable. Factors such as context, familiarity of the human providing petting and relative deprivation from social interaction influenced the amount of time allocated to the petting alternative. More recently, Lazzaroni, Range, et al. (2020) tested different dog populations and found that at the group level they didn’t show a clear preference between a human that had previously provided petting and one that had previously provided food. In some of the dog groups, considering only the animals that made a choice, practically half of the subjects chose the food provider and half the contact provider. Finally, a recent study found that, at the group level, dogs prefer to approach a food reward that is in front of a video projection of the owner facing towards them, over the same food reward in front of a projection of the owner facing away (Bolló et al., 2021). As a potential explanation, the authors suggested that the tendency to approach the owner’s face might be an intrinsically motivated behaviour. Importantly, however, there was considerable individual variation. Relatedly, it has also been suggested that different breeds might show specific preferences for particular stimuli related to the function they

were originally selected for (e.g., in a pilot study, Labrador retrievers were more attracted to water than to social stimuli; Tavares, Magalhães, & de Sousa, 2015).

Cook, Prichard, Spivak, & Berns (2016) noted that direct tests of behavioural preference might be affected by several factors including testing method, socialization and reinforcement history, attention, stimulus salience and satiety. Thus, in their study they used a neurobiological approach instead, revealing a high degree of individual variability in dogs' preference between social (verbal praise) and food reward. Importantly, behaviour in a binary choice task for food bowl or owner was correlated with caudate activation to cues predicting food or praise. Therefore, some individuals showed a stable neurobehavioural preference for social interaction (with the owner) over high value food.

Concerning dogs' preference for collaborative activities, it has been hypothesized that in the domestication process dogs were selected for cooperation with humans (e.g., Gácsi, McGreevy, et al., 2009). Indeed, dogs help humans in a variety of tasks, such as scent detection, search and rescue missions, and provision of guidance to visually impaired persons. Dogs also assist humans in certain experimental situations (e.g., Bräuer, Schönefeld, & Call, 2013; Carballo et al., 2020), but they do not always behave prosocially towards humans (Quervel-Chaumette et al., 2016). Importantly, although they are able to solve cooperative problems with a human partner (e.g. Range, Marshall-Pescini, Kratz, & Virányi, 2019), to our knowledge, no study has directly examined dogs' preference for collaborative activities with humans over individual activities.

In this regard, the study of dogs' individual and social play with a human might provide some insight. It would be interesting to study whether dogs show a preference for social play with a human over individual play, as has been shown in non-human apes (E. MacLean & Hare, 2013). A recent study revealed that dogs attempt to re-engage a human partner when joint play is interrupted, and that they direct these attempts specifically at the human who was previously playing with them instead of a bystander (Horschler et al., 2022). Unfortunately, although the authors note that solitary play was frequent during the interruption period, it was not quantified. The fact that dogs tried to re-establish social play suggests that it might be a more rewarding activity than individual play. It is also worth mentioning, as the authors point out, that the study sample consisted only of retrievers of a population of assistance dogs in training, and that there might be breed

differences (or even individual differences) in the tendency to express re-engagement behaviours.

In summary, individual variability in dogs' preference for social rewards over non-social rewards exists and, as far as we know, no studies have directly addressed dogs' preference for collaborative activities with humans over individual activities. Further research can try to elucidate potential links between sensitivity to social rewards and other social behaviours or personality traits, as well as investigate a possible bias towards collaborative activities.

1.2.2.3. Social maintaining

The third aspect of social motivation refers to individuals' desire to maintain social interactions over prolonged periods of time (Chevallier et al., 2012). This includes so-called maintaining strategies, which are behaviours intended to establish, maintain and enhance social relationships. Among these we find ingratiating behaviours, such as flattery, and reputation management. Although dogs have been shown to demonstrate reputation-like inferences (Kundey et al., 2011), as far as we know, no study has proved that they possess a concept of self-reputation. This is not surprising, since research is still addressing the question of whether dogs show self-representation (e.g. Lenkei, Faragó, Kovács, Zsilák, & Pongrácz, 2019). However, in this context, studies assessing dogs' susceptibility to the so-called audience effect might be informative (e.g., Kiss et al., 2020).

Nonetheless, there is another behaviour that fulfils the function of increasing likeability without the individual's conscious awareness: nonconscious mimicry (i.e. chameleon effect) (Chevallier et al., 2012). The chameleon effect consists of an individual's tendency to imitate the behaviours of a social partner, without awareness or intention (Chartrand & Bargh, 1999). It has been found that intraspecific rapid mimicry is present in dogs, that it is socially modulated (i.e. the stronger the social bond, the higher the level of rapid mimicry) and that it is involved in the sharing of playful motivation (Palagi et al., 2015). In addition, dogs synchronize their behaviours with that of humans in a variety of situations. This behavioural synchronization between dogs and humans depends on the degree of affiliation between the partners, and it is suggested to act as a

social glue (see Duranton & Gaunet, 2018 for a review). Furthermore, dogs prefer humans that synchronize with them, although there is evidence of breed differences in dogs' sensitivity to human behavioural synchronization (Duranton et al., 2019).

Related to the chameleon effect is the concept of conformity, which implies “changing one’s behaviour to match the responses of others” (Cialdini & Goldstein, 2004, p. 606). Although in the human literature, conformity often refers to following the behaviour of a majority, in dogs susceptibility to the behaviour of a single individual is usually examined (see Nagasawa et al., 2020 for an exception). In this sense, several studies have shown that dogs conform to choices made by humans, ignoring their personal preferences, even if it is counterproductive, when presented with human communicative cues. In these studies, some dogs reverse their preference for a plate with a larger quantity or higher quality of food if a human expresses preference towards the small quantity or lower quality food (S. Marshall-Pescini et al., 2011; Sarah Marshall-Pescini et al., 2012; Prato-Previde et al., 2008). Correspondingly, other studies have found that dogs follow human pointing to an empty container, even if they have direct perceptual information of the actual location of the food reward (Szetei et al., 2003) or if they have repeatedly experienced the unreliability of this cue (A. Cook et al., 2014; Kundey et al., 2010). Interestingly, individual differences were observed in the preference to make a choice based on human pointing or on their previous perceptual information (Szetei et al., 2003).

A recent study expanded these findings, and showed that not only dogs, but also cats, prefer to approach the container a human has interacted with over a baited container (Chijiiwa et al., 2021). Although both species were less likely to choose the container associated with the human when the demonstration involved eating the food (i.e., the container was empty) than when it only involved showing the food (i.e., the container remained baited), they chose this container above chance levels in both conditions. The fact that cats also show this preference indicates that this tendency to conform to human’s choices is not necessarily linked to the specific domestication history of dogs but might be related to the selective pressures and experiences that both dogs and cats have as domestic animals that live in close association with humans. The authors also comment that individual differences were observed, which would be important to examine in future studies.

Importantly, it was also recently found that dog’s social susceptibility in a food choice task was increased by social stimulation and oxytocin treatment (Kis et al., 2022).

Dogs who had a previous positive interaction with the owner were more susceptible to the effect of the experimenter demonstration, that is, they chose the smaller quantity (which was favoured by the experimenter) more often than dogs that had been ignored by their owner before the test. However, if during the demonstration the experimenter addressed the subject (i.e., established eye contact), there were no differences between the groups. Pre-treatment with intranasal oxytocin had a similar effect to social stimulation, increasing subjects' preference for the plate favoured by the experimenter, which suggest that oxytocin could mediate this social priming effect.

All in all, there is some evidence supporting the hypothesis that social or affiliative motives might underlie the behaviours presented in this section, including synchronization and conformity. As has been proposed in humans, the idea is that the subject would want to “be like the other” (although not necessarily consciously), which in turn would increase the subject's likeability (see Over & Carpenter, 2012 and references therein). These could also be true in the case of human-dog interactions, and these behaviours could serve the function of maintaining social bonds between humans and dogs (Benz-Schwarzburg et al., 2020). As in previous sections, it is worth highlighting the existence of individual differences in the tendency to express these behaviours.

1.2.3. Empirical evidence of associations between measures of social motivation in dogs

If the behaviours considered in the previous sections are manifestations of a single underlying construct (social motivation), we would expect a correlation between them. In this section I will examine the evidence for and against the association between presumed behavioural indicators of social motivation.

Bray et al. (2017) tested adolescent guide dogs in a battery that included a distraction test, in which the dogs' ability to ignore distracting stimuli (e.g., toys) and approach a calling human instead was examined, and a sustained attention test, that assessed dogs' attentiveness to a human that had commanded the animal to sit. These two behavioural measures could be conceptualized as manifestations of the social orienting component. Interestingly, the average number of toys a dog contacted in the distraction

test and the time they spent facing the experimenter in the sustained attention test loaded on the same factor in an exploratory factor analysis (EFA), showing a negative relationship (although other behavioural measures belonged in this same factor).

E. L. MacLean et al. (2017) presented a considerable number of working and pet dogs with the “dog cognition test battery”. This battery consisted of a series of problem-solving tasks, which examined aspects of social and physical cognition, as well as domain-general cognitive processes. Among others, the battery included a social referencing task, which measured the dogs’ tendency to gaze at a human’s face when social play was interrupted, and an unsolvable task, which assessed the animals’ tendency to seek social help. Importantly, in a factor analysis these two tasks were grouped together, suggesting that they were possibly measuring a single construct. Although the contexts differed, the authors commented that in both tasks the dog could choose between attending to an object versus a human. Hence, the tasks could be interpreted as assessing the social orienting component. On the other hand, if one considers that in the social referencing task a collaborative interaction had been previously established (social play) and regards dogs’ gazing behaviour towards the human as an attempt to re-engage them in the interaction, this task could also be taken as a measure of social reward.

Turcsán et al. (2018) tested Border collies in the Vienna Dog Personality Test (VIDOPET), a test battery aimed to assess personality traits. Among the tests, I highlight here the food choice, problem-solving (cage) and ball play tests. The first test evaluated the dogs’ social susceptibility to the caregiver’s behaviour in a food choice task (i.e., social maintaining). The second test presented a problem that could be solved in a first trial, followed by an unsolvable trial and aimed to examine dogs’ problem-solving ability, their persistence and frustration. In the third test the caregiver threw a ball across the room three times, encouraging the dog during the first two times and ignoring the dog after the third throw to finally leave the ball on a windowsill. The researchers conducted a principal component analysis (PCA) on each test and then performed an EFA with these components. The food choice test fell out of the EFA. The component of the ball play test that was made up of the gaze alternations between ball and caregiver (after the ball was placed on the windowsill) loaded onto the same factor as the component of the problem-solving test that had positive loadings from the duration of orientation towards the cage and the latency to give up, and negative loadings from the duration of gazing at the humans. Given that gaze alternations in the ball play test could reflect social reward and

that the duration of gazing at the humans in the problem-solving test might be an indicator of social orienting, the results of the EFA would suggest a negative relationship between social reward and social orienting.

Brown (2019) conducted various studies in which she analysed different behaviours that have been proposed to be associated with sociability with the objective of determining whether they are truly indicative of a single underlying construct. Among others, the studies included a reinforcer efficacy test, in which the experimenter rewarded palm touches with petting and vocal praise, and a synchronicity test, in which the experimenter walked around an enclosure while the subject was off leash. The dependent variables were the number of palm touches over a two-minute period, and the proportion of the trial in which the subject was in proximity to the experimenter (within arm's length), respectively. Although not explicitly mentioned, the correlation matrix seems to show a weak positive correlation between reinforcer efficacy (i.e., social reward) and synchronicity (i.e., social maintaining) in two of the studies.

In their second study, Brown included a reunion test, in which the experimenter reunited with the subject after a 2-minute separation phase. Behaviours in this test included approaching, establishing physical contact, gazing, orienting and jumping, which in this context could be indicative of the social reward component of social motivation. Interestingly, the researcher found moderate positive correlations ($r = .40$ and $.55$) between reinforcer efficacy and behaviours in the reunion test. Only a weak correlation between synchronicity and the orienting behaviour during the reunion test is apparent in the correlation matrix. In the PCA of both studies, behaviours from these tests didn't group together.

Pedretti et al. (2021) examined the effect of oxytocin administration in dogs' human-directed behaviour in a behavioural synchrony and a shared attention test. They found that artificially elevated levels of oxytocin were associated with the duration of proximity in the synchrony test (i.e., location synchrony) and with the duration of gazing at the owner in the shared attention test. The researchers interpreted these results as evidence that oxytocin can increase social motivation.

Overall, there is limited evidence of the association between potential behavioural indicators of social motivation in dogs and further research is warranted.

1.3. SOCIABILITY

After applying Chevallier et al.'s conceptual scheme of human social motivation to dogs, one might wonder how it relates to sociability. On the one hand, sociability in dogs has been frequently operationalized as the behavioural tendency to approach and interact with unfamiliar humans (e.g., Bentosela et al., 2016; Bhattacharjee et al., 2021; Jakovcevic et al., 2012; see also Table A.1). Thus, one might ask whether more sociable dogs (i.e., those that tend to be in proximity to and establish interactions with strangers), also show an attentional bias towards social stimuli (i.e., social orienting), find social interactions more rewarding (i.e., social reward) and deploy more strategies to enhance and maintain their social bonds (i.e., social maintaining) than less sociable individuals.

On the other hand, sociability has been assessed as a personality trait in multiple species, including dogs (Gartland et al., 2021; Gosling & John, 1999). As a personality trait, sociability encompasses consistent behaviours in different contexts and across time. How does social motivation relate to sociability understood as a personality trait? To tackle these questions, in this section I will begin by addressing sociability as a personality trait in dogs, reviewing its conceptualization and measurement.

1.3.1. Sociability as a personality trait in dogs

In non-human animals (henceforth, animals), personality is usually defined as interindividual differences in behaviour that are consistent across time and contexts (Kaiser & Müller, 2021; Stamps & Groothuis, 2010). Measurement of animal personality often involves observation of behaviours, contrary to human personality studies (Bell & Bensky, 2020). Still, several methods have been used in the animal personality literature, and, particularly in the assessment of dog personality, three main methods can be identified: test batteries, observational tests and questionnaires (Amanda C. Jones & Gosling, 2005; see also Fratkin, 2017; Gartner, 2015; Amanda Claire Jones, 2008; Ádám Miklósi et al., 2014; Rayment et al., 2015; Svartberg, 2007; Wiener & Haskell, 2016 for reviews on the study of dog personality). In test batteries, subjects are presented with a specific set of stimuli in controlled environments to measure their behaviours, while in observational tests usually subjects' reactions to naturally occurring stimuli in non-

controlled environments are examined. In questionnaires, information is gathered regarding the subjects' behavioural tendencies, typically from ratings provided by the animal's caregiver.

Sociability can be broadly defined as an individual's tendency to associate with other individuals (excluding aggressive and reproductive behaviours) (Gartland et al., 2021). Consistent interindividual differences in this social tendency have been found in a diverse range of species, and consequently sociability has been considered a personality trait with substantial generality across species (Gartland et al., 2021; Gosling & John, 1999). In our project we are only concerned with dogs' sociability towards humans, so we will not address dogs' intraspecific sociability, and we will use the term "sociability" to refer only to human-oriented sociability unless otherwise stated. We define sociability as a personality trait reflecting dogs' positive interest for social interactions with humans and their friendly attitude in such interactions. In dogs, sociability has emerged as a personality trait in numerous analyses (Amanda C. Jones & Gosling, 2005; McConnell et al., 2022; Mirkó et al., 2012; Salonen et al., 2021; Svartberg, 2005, 2021; Svartberg & Forkman, 2002; Turcsán et al., 2018; see also Brown, 2019 for a review) and, importantly, has shown temporal consistency (Fratkin et al., 2013; Amanda Claire Jones, 2008; J. M. Ley, McGreevy, et al., 2009; Salonen et al., 2021; Svartberg et al., 2005).

Studies differ in the methods they use to assess sociability in dogs (i.e., questionnaires versus behavioural tests), but they typically use data reduction techniques (i.e., factor or principal component analysis) that group the items or behavioural measures into factors/components that are subsequently labelled according to their content. This means that what lies behind the sociability label can vary considerably, going from a mix of simple adjective-based items (e.g., "brave", "mistrustful", "initiative"; Mirkó et al., 2012) to a combination of components derived from behavioural reactions to different subtests (e.g., approach, greeting and tail wagging in a greeting subtest, and play behaviour in a ball play subtest; Turcsán et al., 2018). In addition to this, as pointed out by Amanda C. Jones & Gosling (2005), there isn't a standard lexicon of traits in the dog personality literature. Thus, the trait that captures the tendency to establish friendly interactions with other individuals has not only been called "sociability", but has also received labels such as "friendliness", "extraversion", "affiliation" or "affability" (Fratkin, 2017; Amanda Claire Jones, 2008).

Regarding behavioural tests, Table A.1 compiles references of some of the studies that have examined sociability-related constructs in dogs, presenting the different terms or expressions that have been used to refer to these constructs, along with a description of the test used, the variables measured and the sample type. As can be seen, sociability is often assessed through an encounter with an unfamiliar individual, in which usually proximity and physical contact variables are measured. An example of a paradigm of this kind, that has been used frequently as a measure of sociability, is the one developed by Jakovcevic et al. (2012). In this case, sociability is typically operationalized as the tendency to approach and interact with unfamiliar individuals, and thus it is assumed that sociability can be measured with a single test. Other studies employ test batteries instead, which include multiple subtests, again often involving interaction with an unfamiliar human. In this case, sociability or related constructs emerge through factor or principal component analyses. The Dog Mentality Assessment (DMA) is an example of a test battery that has been used recurrently in studies of dog personality (Svartberg & Forkman, 2002).

Regarding questionnaires, Table A.2 shows some of the questionnaires that include factors or facets related to sociability (see Wiener & Haskell, 2016 for a review on dog personality questionnaires). In the table, the personality dimensions found in each questionnaire are presented, along with the specific sociability-related factor/facets, their description and constituting items. References to studies which offer evidence of validity and reliability are also provided in Table A.3, but this table does not pretend to be exhaustive. As illustrated in the table, sociability-related constructs have been measured by items consisting of adjectives (sometimes accompanied by definitions or examples) and/or behavioural descriptions. Caregivers (owners) are asked to rate their dog, often using a 5-point scale. Items commonly refer to a tendency to seek proximity or contact with humans (or the opposite, being reserved or uninterested in people).

Sometimes items referring to fear or aggression are mixed with sociability items (e.g., Kubinyi et al., 2009; J. M. Ley, Bennett, et al., 2009; Mirkó et al., 2012). Typically, fearfulness and aggression have been regarded as separate dimensions from sociability (Amanda C. Jones & Gosling, 2005), but this division is not always clear-cut. For example, in the case of the Canine Behavioural Assessment and Research Questionnaire (C-BARQ), although sociability items were included initially, they were excluded posteriorly given their moderate to strong negative correlations with items of the

“Stranger-directed aggression” and “Stranger-directed fear” factors (Hsu & Serpell, 2003). In the Dog Personality Questionnaire (DPQ), although the “Companionability” facet is related to sociability, the “Aggression towards people factor” also makes reference to friendliness towards people (Amanda Claire Jones, 2008). In this questionnaire, aggression and friendliness are seen as opposite ends of a spectrum, and the factors “Aggression towards people” and “Fearfulness” are correlated (Amanda Claire Jones, 2008). A similar view was shared by Svartberg (Svartberg, 2005, 2007), who commented that the trait that reflects the attitude towards strangers has a “negative side” that seems to be connected to social fearfulness and aggressiveness (an attitude of reservation or hostility), and that “perhaps it is the positive side – a positive interest and a friendliness towards unfamiliar persons – that motivates a use of a separate sociability trait” (Svartberg, 2007, p. 193).

Another possible view is that sociability is a dimension that goes from a lack of interest to positive interest toward people. It is conceivable that an individual is uninterested in other individuals, without being fearful or aggressive. In this sense, sociability would be a separate dimension from fearfulness and aggression. This is similar to what Zimen (1987) proposed when he suggested that there were two separate behavioural tendencies involved in wolf pups’ human-directed social behaviour. One trait, which he labelled “tendency toward socialization” reflected a “disposition to approach and engage in harmonious interaction” and was comprised of behaviours that can be described as “friendly or affectionate” (Zimen, 1987; pg. 277). This trait represents a sociable-indifferent axis, and its main behavioural measure is a spontaneous tendency to approach humans, while its absence is reflected in a lack of interest or passive avoidance. On the other hand, the second trait is the “tendency to flight”, which refers to the tendency to retreat from humans. It represents a timid-confident axis, with individuals on one end of the axis being described as “timid”, “fearful” or “shy”. Apart from these ideas, an additional consideration is that fearfulness could act as a suppressor in the expression of sociability (see Rayment et al., 2015 and references therein).

It is also worth mentioning that in some cases, playfulness measures are included in the sociability factor (e.g., (Chapagain et al., 2020; Svartberg, 2006; Svartberg & Forkman, 2002; Turcsán et al., 2018, 2020). For example, in their factor analysis of scores in a series of behavioural subtests, Svartberg & Forkman (2002) found that some variables had high loadings on both the factor “Playfulness” and on the factor “Sociability”.

Moreover, in the case of the Retrievers group, the factors “Playfulness” and “Sociability” merged to form a combined factor: “Sociability-Playfulness”.

Some studies have examined the correlation between factors of different questionnaires (e.g., Henriksson, 2016; Posluns et al., 2017; Rayment et al., 2016). Table A.4 provides some examples of the associations that have been found, with a focus on sociability-related factors. As can be noted, there is some correspondence between the sociability-related factors of different questionnaires. For example, “Companionability” from DPQ has a moderate positive correlation with “Amicability” from Monash Canine Personality Questionnaire-Revised (MCPQ-R) (Henriksson, 2016). A moderate negative correlation has been found between the MCPQ-R factor “Amicability” and the C-BARQ factors measuring stranger-directed aggression and fear, but not with the “Attachment-attention seeking” factor (Henriksson, 2016; Rayment et al., 2016). In contrast, the DPQ facet “Companionability” showed a moderate positive correlation with C-BARQ “Attachment-attention seeking”, and only a weak negative correlation with C-BARQ factors “Stranger-directed fear” and “Stranger-directed aggression” (Henriksson, 2016). As expected, these latter C-BARQ factors correlate with DPQ factors measuring aggression and fearfulness (Henriksson, 2016; Posluns et al., 2017).

A certain degree of convergence has also been found between sociability measures from behavioural tests, questionnaires and everyday behaviours, giving partial support to the construct validity of the corresponding traits. For example, Jakovcevic et al. (2012) examined the correlations between their sociability test and factors from the C-BARQ. The “Stranger-directed fear” factor correlated with the latency to establish physical contact and the duration of proximity in the passive phase of the test. Curiously, the duration of proximity and of physical contact in the passive phase correlated with the “Trainability” factor, which suggests a relationship between sociability and obedience, that has also emerged in other studies (e.g., Turcsán et al., 2018, 2020).

Svartberg (2021) recently examined whether a sociability factor, obtained through hierarchical factor analysis on behavioural ratings of a series of subtests, correlated with subjective rating scales in the same subtests (internal construct validity) and with a questionnaire composed of items reflecting everyday behaviours (external construct validity). The sociability factor had positive loadings from greeting behaviours and negative loadings from fear-related behaviours in subtests which involved an interaction with an unfamiliar or an oddly dressed person. This factor was found to have strong

positive correlations with the score on the subjective scale “people friendly” in the same subtests. That is, ratings of specific behaviours (e.g., intensity of greeting or fear-related behaviours) in behavioural subtests converge with ratings on subjective scales (e.g., score on how “people friendly” the dog is).

Furthermore, the sociability factor had moderate positive correlations with the questionnaire subscales “Stranger-directed interest” and “Human-directed play interest”, and negative correlation with the “Stranger-directed fear” subscale. In a previous study, the sociability factor derived from the DMA was found to correlate with the “Stranger-directed fear” and “Stranger-directed aggression” factors of the C-BARQ (Svartberg, 2005). The “Companionability” facet from the DPQ correlated with behavioural ratings in categories such as “interested in people” or “affectionate” in subtests involving an encounter or interaction with a stranger and engagement in play (Amanda Claire Jones, 2008). The “Stranger-directed sociability” factor in the MCPQ-R also showed correlations with sociability-related behaviours, such as greeting behaviour towards an unfamiliar human and play behaviour with an experimenter (Mirkó et al., 2013).

1.4. SOCIAL COGNITION

As previously discussed, several hypotheses have been proposed to explain the origin of dogs’ social cognition, some of which suggest a link between sociability/social motivation and socio-cognitive abilities. According to the *emotional reactivity hypothesis*, the ability to read human signals might be a by-product of selection for tameness (i.e., selection against fear and aggression and in favour of social contact with humans) (Hare & Tomasello, 2005a, 2005b). Other hypotheses (e.g., *cooperation and attention hypothesis*, *synergistic hypothesis*) highlight the importance of dogs’ tendency to gaze at the human face or their attention towards humans (i.e., social orienting). The *Two Stage hypothesis* emphasizes the role of dogs’ social experiences in the development of their socio-cognitive skills (Udell et al., 2010b). Although these hypotheses were presented in the context of wolf-dog comparisons, their implications can be extended to comparisons within species (i.e., between individuals). Hence, these hypotheses point toward a positive correlation between dogs’ sociability/social motivation measures and

their performance in socio-cognitive tasks at the individual level (see Table 1.1 for a summary of the hypotheses and their predictions).

Before pondering how sociability and social motivation might relate to social cognition, in this section I will briefly review current knowledge about dogs' socio-cognitive abilities.

1.4.1. Social cognition in dogs

The literature dedicated to the topic of social cognition in dogs is extensive and ever-expanding. The review I will present here is far from comprehensive, but interested readers can find thorough reviews in Bensky et al. (2013); Benz-Schwarzburg et al. (2020); Huber & Lonardo (2023); Jardat & Lansade (2022); Sarah Marshall-Pescini & Kaminski (2014); Udell & Wynne (2008); Wynne (2021).

The upsurge in studies addressing dogs' social cognition was probably triggered in part by the observation that our canine companions outperformed our closest living relatives, chimpanzees, in following human communicative gestures (Hare et al., 2002). Since then, the claim that dogs possess exceptional socio-cognitive skills has been made repeatedly, although as we gain more information regarding the cognitive abilities of other species and we grow aware of the influence of methodological and experiential factors, the degree to which dogs' social cognition is truly exceptional is questionable (Clark et al., 2019; Jardat & Lansade, 2022; Krause et al., 2018; Lea & Osthaus, 2018).

In any case, numerous studies prove that dogs display remarkable socio-cognitive abilities in their interspecific interactions with humans. Dogs have been shown to be able to socially learn from humans in some contexts, including social referencing (Bensky et al., 2013; Jardat & Lansade, 2022; Pongrácz, 2014). They are also adept at communicating with humans, using vocalizations, body positioning and gaze alternations, and taking into account humans' attentional states (Bensky et al., 2013; Jardat & Lansade, 2022; Udell & Wynne, 2008). Indeed, there is evidence that dogs are sensitive to humans' gaze direction and attentional states, can follow humans' gaze into distant space, show geometrical gaze-following, and have some understanding of our visual, and even auditory, perspective (Bensky et al., 2013; Benz-Schwarzburg et al., 2020; Bräuer, 2014;

Huber & Lonardo, 2023; Jardat & Lansade, 2022; Udell & Wynne, 2008; Wynne, 2021). Moreover, they form multimodal representations of humans and their emotions (Benz-Schwarzburg et al., 2020; Jardat & Lansade, 2022). Certainly, it has also been demonstrated that dogs reliably follow various human communicative signals and are sensitive to ostensive cues (Bensky et al., 2013; Benz-Schwarzburg et al., 2020; Jardat & Lansade, 2022; Reid, 2009; Topál et al., 2014; Udell & Wynne, 2008; Wynne, 2021). In the present research, we focus on dogs' ability to use human communicative gestures and their sensitivity to humans' attentional states.

The use of human communicative cues by non-human species has been mainly studied through object-choice tasks (OCTs) (for cross-species reviews see Clark et al., 2019; Krause et al., 2018; Ádam Miklósi & Soproni, 2006). In this paradigm, typically two or three opaque objects are presented, the human indicates which one of them is baited through a gesture, and whether the subject follows the cue and chooses the target object by approaching or touching it is assessed. A control condition in which the experimenter doesn't indicate any container is often included to discard the possibility that subjects are selecting the baited container based on olfactory cues, and it has been found repeatedly that dogs don't perform above chance level in this condition (e.g., Á. Miklósi et al., 1998; Riedel et al., 2008; Udell et al., 2010a; see also Szeteci et al., 2003).

The most common human cue used in OCTs is pointing, but other cues such as head turns and gazing have been used as well. Although performance is affected by the type of cue presented, dogs are able to use many different human cues successfully, including pointing, head turns and gazing, and can generalize this behaviour to relatively novel cues such as "cross-pointing" or leg pointing (reviewed in Bensky et al., 2013; Benz-Schwarzburg et al., 2020; Jardat & Lansade, 2022; Reid, 2009; Udell & Wynne, 2008). Different hypotheses have been proposed to explain dogs' success in following human communicative gesture at the proximate (e.g., associative learning versus understanding of the referential nature of the cues) and ultimate level (domestication hypotheses versus life experiences) (e.g. Kaminski & Nitzschner, 2013; Reid, 2009; Soproni et al., 2001; Udell et al., 2010a).

Regarding dogs' sensitivity to human attentional states, studies using different experimental paradigms have proved that dogs are sensitive to behavioural and environmental cues associated with visual attention (reviewed in Bensky et al., 2013; Benz-Schwarzburg et al., 2020; Bräuer, 2014; Huber & Lonardo, 2023; Jardat & Lansade,

2022; Udell & Wynne, 2008). Dogs discriminate between attentive and inattentive humans using cues such as head and body orientation, visibility of the eyes and whether they are open or closed in several contexts, including begging for food, seeking interaction, communicating, obeying a command, playing fetch, following communicative gestures or stealing food. During their interactions and communication with humans, they also consider our visual field. For example, they prefer to position themselves in front of a human to drop a retrieved object even when the human has their back turned to them (Gácsi et al., 2004; Hare et al., 1998). They also modulate their position in the room based on the owners' body orientation in a context in which they can communicate about the location of unreachable food, moving around when the owner had their back turned to position themselves face-to-face (Savalli et al., 2014). This might imply that dogs have "some understanding of humans' visual field and make use of this information in a functional way both in cooperative (e.g., begging, obeying a command) and competitive contexts (e.g. stealing)" (Huber & Lonardo, 2023; pg. 287). Again, there are different interpretations regarding the proximate mechanisms that enable dogs to succeed in these tasks (associative processes versus theory of mind) and the evolutionary origin of these skills (e.g., Bensky et al., 2013; Call et al., 2003; Huber & Lonardo, 2023; Udell et al., 2011; Udell & Wynne, 2011).

Studies examining dogs' socio-cognitive abilities typically focus their discussion on performance at the group level, and individual variation is considered noise. However, the importance of an individual-level approach on cognitive studies is increasingly being recognized (Arden et al., 2016; Bensky et al., 2013; Krause et al., 2018; Ádám Miklósi & Kubinyi, 2016). Studies that share information on individual performance or on the number of subjects that performed above chance level provide evidence of the existence of individual differences in dogs' success in OCTs (e.g., (Agnetta et al., 2000; Dorey et al., 2010; Gácsi, Kara, et al., 2009; Gácsi, McGreevy, et al., 2009; Á. Miklósi et al., 1998; Riedel et al., 2008; Udell et al., 2010a, 2014; Udell, Giglio, et al., 2008), as well as in tests of attentional state discrimination (e.g., (Call et al., 2003; Cooper et al., 2003; Udell et al., 2011; Virányi et al., 2004).

1.5. ASSOCIATIONS BETWEEN SOCIAL MOTIVATION, SOCIABILITY AND SOCIAL COGNITION

1.5.1. Social motivation and sociability

In this section I will explore the potential connection between social motivation and sociability. First, I will briefly refer to proposals made in the human personality literature regarding the associations between motivation and personality, which I will then use as a basis for my discussion on possible links between sociability and social motivation specifically. Finally, I will present studies that might provide evidence of associations between sociability and social motivation in dogs.

1.5.1.1. Motivation and personality in the human literature

Personality traits in humans have been defined as consistent individual patterns of thoughts, feelings and behaviours (e.g., (Baumert et al., 2019)), and have mainly been measured using self-report (Bell & Bensky, 2020). In the human personality literature there have been two main approaches to the study of personality: a *structural approach* and a *process-oriented approach* (Zeigler-Hill et al., 2019). In the former, researchers typically focus on describing the structure of personality (i.e., the number of personality traits, their interrelation and hierarchy), while in the latter, researchers examine the associations between situations and behaviour and try to ascertain the socio-cognitive mechanisms underlying behaviour (Zeigler-Hill et al., 2019). Personality research has mostly focused on the description of individual differences, with studies aiming to determine the structure of human personality, as well as trying to predict life outcomes based on the personality traits that emerge from the structural analyses. However, there has been a call for more research on the explanatory aspects of personality and an integration with the descriptive approach (Baumert et al., 2019; Blum et al., 2021; Corr et al., 2013; Fleeson & Jayawickreme, 2015; Robinson et al., 2019; Yang et al., 2014; Zeigler-Hill et al., 2019). That is, personality psychology should not only list and describe the traits that constitute human personality and their interrelations, but should also try to explain why individuals behave the way they do. In other words, personality research

should not be limited to a structural (descriptive) approach, but also include a process-oriented (explanatory) one and try to integrate both (e.g., Whole Trait Theory: Fleeson & Jayawickreme, 2015).

Of interest in the present context is the fact that both approaches have incorporated motivational constructs. In the case of the structural approach, however, this leads us to the debate about what constructs should be included in the concept of personality traits (see Yang et al., 2014; Zillig et al., 2002). Although according to the definition previously provided, personality traits would include cognitive, affective and behavioural aspects, authors differ on the emphasis they put on each of these dimensions, or even in the aspects they include in their conceptualizations of traits (Yang et al., 2014; Zillig et al., 2002). An important point to bear in mind is that a construct can't be both a description and an explanation of another construct. Therefore, if motivational constructs are considered a component of personality traits, they can't be used as explanations of these traits. Examples of frameworks in which motivational constructs are incorporated as components of traits are the ABC(D) models by Wilt & Revelle (2015) and Zillig et al. (2002), which suggest that personality traits have affective, behavioural and cognitive (and desire) components.

Regarding the process-oriented approach, in search for the explanatory mechanisms of consistent interindividual differences in behaviour, numerous theoretical models and empirical approaches have been proposed (e.g., Baumert et al., 2019; Corr & Krupic, 2017; DeYoung, 2015; Dweck, 2017; Fleeson & Jayawickreme, 2015; McCabe & Fleeson, 2016; Quirin et al., 2020; Read et al., 2010; Robinson et al., 2019; Yang et al., 2014). Some of these have revolved around the potential motivational processes implicated in personality (Boag, 2018; Corr et al., 2013; Corr & Krupic, 2017; Denissen & Penke, 2008; Dweck, 2017; McCabe & Fleeson, 2016; Read et al., 2010; Robinson et al., 2019; see also Boag, 2018; Zeigler-Hill et al., 2019 for a review). While these proposals agree that motivation is a fundamental aspect of personality, the theoretical models of motivation, motivation-related constructs or motivational units they use differ (e.g., socio-cognitive processes: Fleeson & Jayawickreme, 2015; Robinson et al., 2019; neuropsychological approach-avoidance systems: Corr et al., 2013; Corr & Krupic, 2017; Read et al., 2010; goals: McCabe & Fleeson, 2016). These accounts usually focus on the manifestations of traits (i.e., behaviours) and propose motivational processes that might

explain them, sometimes linking specific traits with particular motivational processes, constructs or systems.

1.5.1.2. Potential links between sociability and social motivation in dogs

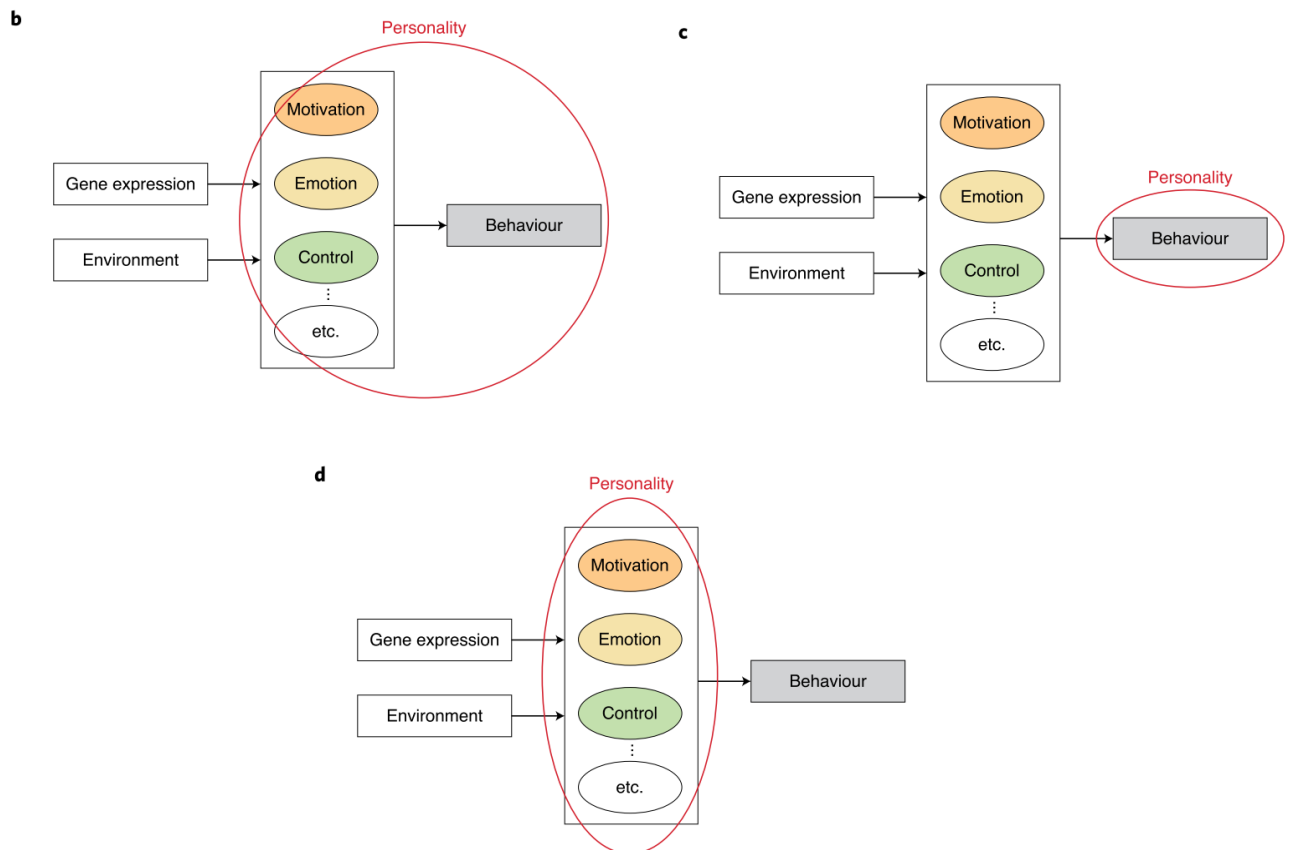
As illustrated above, the structure of dog personality has been studied by several researchers, and although there is still no consensus regarding the number of dimensions, in many of these assessments a factor emerges that usually reflects an individual's friendly disposition in social interactions, which is typically labelled sociability. Paralleling research in human personality, it might be interesting to move from a descriptive (structural) approach to an explanatory (process-oriented) one. That is, assuming that sociability is a personality trait, what are the processes involved in its expression? If we want to explain why a sociable individual behaves in a particular way, it is not useful to invoke the personality trait as an explanation (e.g., "Fido approaches and interacts in a friendly manner with an unfamiliar human because Fido is sociable"), rather one should look for the mechanisms that underlie the trait, such as cognitive and motivational processes. One such process could be social motivation.

Dubois et al. (2020) presented possible causal models of personality that can help elucidate the potential links between social motivation and sociability (see Figure 1.1). These models explore the constitutive and causal relations between personality, behaviour, and psychological variables such as motivation and emotion. As mentioned above, in human personality literature, personality traits are often defined as consistent individual patterns of thoughts, feelings and behaviours. This would fit with model B, in which personality is constituted by psychological variables, as well as overt behaviour. An example of models of this type are the ABC(D) models mentioned above, in which personality traits have affective, behavioural, cognitive (and desire/motivational) components. In contrast, definitions of personality in non-human animals typically refer to consistent interindividual differences in behaviour (Kaiser & Müller, 2021; Stamps & Groothuis, 2010). Therefore, this definition would seem to imply model C, in which personality is identified with patterns of observed behaviour, instead of being a cause of it. As Dubois et al. (2020) comment, while we frequently infer personality from behaviour, and this is especially true in the case of non-human animals, this does not

mean that behaviour literally constitutes personality. While a personality trait, such as sociability, can be defined as a disposition to behave in a certain way (e.g., a disposition or tendency towards friendly behaviour in social interactions), this suggests that a constitutive element of personality is causing that behaviour (Dubois et al., 2020). This leads us to models in which personality has a casual role in behaviour. From the models presented by Dubois et al. (2020), I would like to mention here model D, in which personality is constituted by a set of psychological variables, such as motivation and emotion, and has causal effects on behaviour.

Figure 1.1

Causal Models of Personality



Note. Schematics of a selection of models that relate personality to other variables. Red circles denote constitutive relations and arrows denote causal relations. In model B, personality is constituted by patterns of psychological variables and overt behaviour. In model C, personality is just identified with patterns of observed behaviour. In model D, personality is constituted by

patterns across a set of psychological variables and has a causal role on behaviour. Adapted from Dubois et al. (2020).

Now that we have reviewed some possible models, we can try to hypothesize the relationship between social motivation and sociability. Social motivation has been defined as “a set of psychological dispositions and biological mechanisms” (Chevallier et al., 2012, p. 232), therefore it is a psychobiological variable (that can be measured through behavioural manifestations). If we assume that sociability is a personality trait, following models B and D would lead us to hypothesize that social motivation (a psychological construct) is a component of sociability. Therefore, according to these models, social motivation cannot be used as an explanation of sociability since this would imply circularity. To avoid circularity, the *explanans* (what is used to explain something) needs some independence from the *explanandum* (what is explained) (Baumert et al., 2019; Boag, 2018). In the case of model D, however, social motivation can be used as an explanation (cause) of (sociable) behaviour. In this model, behaviour is not a component of personality, but an effect. Behaviour is then separate from the personality trait (i.e., sociability), and the trait has psychological variables as its components (i.e., social motivation is a component of sociability). Behaviour can be used to infer a personality trait, such as sociability. However, behaviour can also be used to infer psychological constructs, such as social motivation. Since, according to this model, social motivation is a component of sociability, behavioural manifestations of social motivation are also behavioural manifestations of sociability (and viceversa). In this regard, Jaswal & Akhtar (2019) noted that the behavioural manifestations of social motivation proposed by Chevallier and collaborators are remarkably similar to descriptions of extraversion.

An alternative that might avoid the circularity issue above is considering personality as constituted only by behaviour (model C in Dubois et al., 2020). In this case, social motivation (and other psychological variables) are the causes of sociable behaviour, and sociable behaviour is equivalent to sociability. Equating personality with behaviour might be seen as reductive, but as commented above, is consistent with common definitions of personality in animals. If we assume that sociability corresponds to a cluster of behaviours, social motivation might be responsible for the clustering of these behaviours (Blum et al., 2021). In other words, interindividual differences in social motivation might account for interindividual correlation among behaviours that form the

cluster labelled “sociability”. These correlated behaviours can be measured directly (through behavioural tests) or indirectly (through questionnaires). Nevertheless, it is important to mention that this view assumes that statistical clusters of interindividual differences in behaviour correspond to common underlying causes of behaviour, but this is an empirical question that requires testing (Baumert et al., 2019; Blum et al., 2021).

Finally, it might be interesting to consider why social motivation and sociability might not be related in some cases. Again, if one equates sociability with sociable behaviour, for example, the tendency to approach and interact in a friendly manner with other individuals, an individual that is unsociable might still have a high social motivation. As mentioned previously, in the human literature conceptual models have been presented that apply approach and avoidance theory to social withdrawal (Asendorpf, 1990). Although I have focused on the positive side of sociability and social motivation, it is important to consider the negative side as well. The social motivation concept of Chevallier et al. (2012) is to some extent analogous to a social approach motivation. What I have not been considering is the role that social avoidance motivation might have in the expression of sociable behaviour and its interaction with social approach motivation. The lack of sociable behaviours (i.e., unsociability) might be a result of different combinations of social approach and avoidance motivations (Asendorpf, 1990). The conclusion is that highly sociable individuals have high social (approach) motivation (and low social avoidance motivation), but not every individual with a high social (approach) motivation is sociable (i.e., expresses sociable behaviours).

1.5.1.3. Empirical evidence of associations between social motivation and sociability in dogs

1.5.1.3.1. Social orienting

Social orienting refers to attentional priority granted to social signals or objects with social importance (Chevallier et al., 2012). As commented in a previous section, some studies have found that dogs show preferential looking towards biological motion. Importantly, it has been suggested that dogs’ preferential looking is modulated by the social relevance of the stimulus (Delanoëje et al., 2020; Ishikawa et al., 2018), and the

sociability levels of the individuals have been shown to influence looking patterns in this paradigm (Ishikawa et al., 2018). To measure sociability, dogs' caregivers were asked to rate their dog on six sociability questions, which addressed the dog's friendliness, aggressiveness and fear towards unknown dogs and humans. High-sociability dogs preferred the frontal human point-light display over the lateral view, suggesting that more sociable dogs are more attentive towards a visual cue with stronger social relevance, such as a frontal view of a human (Ishikawa et al., 2018).

However, Kovács et al. (2016) found that positive attentional bias towards biological motion disappeared in individuals pre-treated with oxytocin. This finding is unexpected, since other studies in dogs have shown that administration of oxytocin enhances social orienting and sociability-related behaviours (orientation and affiliation: Romero et al., 2014; gazing: Kovács, Kis, Pogány, et al., 2016; Nagasawa et al., 2015; gazing but not sociability: Barrera et al., 2018). Still, the authors explained this finding by suggesting that oxytocin pre-treatment might not necessarily reduce the attractiveness of the social stimulus, but might facilitate the identification of biological motion stimuli, which would result in the subjects focusing on the less recognizable stimulus (i.e., non-biological motion stimuli) (Kovács, Kis, Kanizsár, et al., 2016). In any case, it has been recognized that the role of oxytocin in dog-human social interactions is complex and is frequently oversimplified (see Buttner, 2016; Kis et al., 2017 for reviews). On the other hand, it has been debated whether dogs recognize the identity of the figure represented in the display (Eatherington et al., 2021).

Recently, Galambos et al. (2021) used the social motivation framework provided by Chevallier et al. (2012) in a study on dogs, focusing on the social orienting component. Specifically, they wanted to study the effects of social and non-social distractor stimuli on dogs' performance in a visual cue-response association task. The most important aspect, though, was comparing how dogs with different levels of social competence were affected by each type of distractor stimuli. This study was inspired by observations in autism research, which have revealed that the distracting effect of social and non-social task-irrelevant stimuli differs between people with autism spectrum disorder (ASD) and neurotypical people. While the latter are more easily distracted by task-irrelevant social stimuli, individuals with ASD find non-social stimuli more distracting, and they might even be unaffected by socially salient stimulus (see references in Galambos et al., 2021).

To measure social competence in dogs, the authors developed a questionnaire, the Interspecific Social Responsiveness Survey, based on the diagnostic criteria of ASD. Through exploratory factor analysis they extracted three factors: 1) contact seeking and synchronization, 2) behaviour towards strangers, and 3) attention to human communicative signals. Factor 2 included items that examined the degree of playfulness with strangers, differentiation between humans, avoidance of strangers and anxiousness when being alone with a stranger. Therefore, the content of this factor closely aligns with what has typically been labelled sociability, and the authors considered it as an indicator of sociability levels. In general, levels of social competence (i.e., factor scores in the questionnaire) modulated the effect of the distracting stimuli. Dogs with higher social competence (including sociability levels, reflected in factor 2 scores) were more distracted by the social stimulus (human face) compared to the non-social one (book cover).

There is evidence from previous studies that suggests that sociability modulates dogs' gazing at the human face. At the species level, dogs had higher sociability scores than wolves in a behavioural test in which latency to approach and time spent in proximity to unfamiliar and familiar humans were measured (Bentosela et al., 2016). Notably, dogs also gazed longer than wolves at a human face in the presence of out-of-reach food (Bentosela et al., 2016). Within species, a parallel result was found, with highly sociable dogs showing longer durations of spontaneous gazes at the human face when food is out of reach (Putrino et al., 2014). Furthermore, more sociable dogs (i.e., those who spent more time in physical contact with an unfamiliar person) have been found to persist longer in the gazing behaviour when it is no longer reinforced (i.e., during extinction) than less sociable individuals (Jakovcevic et al., 2012). These results suggest that more sociable animals might remain attentive to humans for longer durations.

Lastly, vonHoldt et al. (2017) tested wolves and dogs in a sociability test with a passive and an active phase with both an unfamiliar and a familiar human, as well as in a solvable task. They created three indices from the behaviours coded in these tests: hypersociability (HYP), social interest to strangers (SIS) and attentional bias to social stimuli (ABS). The HYP index was the sum of the proximity duration in all phases of the sociability test, and thus represented overall engagement with humans, while the SIS index only considered the proximity duration in the two phases with the unfamiliar experimenter, hence measuring engagement with unfamiliar humans exclusively. The

ABS index was obtained from the human-present condition of the solvable task and consisted in the ratio between the duration of gazing at the experimenter to the sum of duration of gazing at the experimenter and at the puzzle box. That is, the index reflected the proportion of attention directed towards the human. The authors mention that these three indices were correlated, although when analysing the raw data provided by the researchers, I only found a significant correlation between HYP and SIS in dogs (which is expected since, from my understanding, SIS is part of HYP). In addition, they conducted a PCA on the behaviours to obtain orthogonal (i.e., uncorrelated) components, but some behaviours showed cross-loadings and the sign of the loadings implied a negative relationship between the proportion of time gazing at the human in the unsolvable task and the duration of proximity to the familiar human during the sociability test.

1.5.1.3.2. Social reward

An additional manifestation of social motivation is finding social interactions rewarding. In this case, I am interested in potential links between sociability levels and responsiveness to social rewards, as well as preference for collaborative over individual activities.

Brown (2019) investigated the association between sociability and the efficacy of social reinforcers. As mentioned previously, the researcher conducted two studies with the aim of determining whether different behaviours that have been proposed to be associated with sociability are truly indicative of a single underlying construct. Among others, the studies included a sociability test, in which the experimenter knelt down and interacted with the subject if he/she approached, and a reinforcer efficacy test, in which the experimenter rewarded palm touches with petting and vocal praise. Although they didn't compare it to the efficacy of a non-social reinforcer, they examined the association between the number of palm touches over a two-minute period, and behaviours in the sociability test (including measures of proximity, physical contact, gazing, orienting, and jumping). Regarding the results of the first study, the author doesn't mention any relevant correlations between the tasks (the correlation matrix seems to show a weak correlation between reinforcer efficacy and proximity), and in a PCA they were separated in different components. In the second study, however, there were moderate positive correlations

(Pearson correlation coefficients between .42 and .55) between reinforcer efficacy and sociability behaviours. This study also added a reunion test, in which the experimenter reunited with the subject after a separation period. Correlations between behaviours in the reunion test (which could be taken as a measure of social reward) and corresponding behaviours (i.e., approaching, touching, gazing, orienting, jumping) in the sociability test were moderate at best (e.g., $r = .52$), except for orienting, which showed a strong correlation ($r = .76$). In the PCA, latency to approach in the sociability test belonged to the same component as touching and jumping in the reunion test.

Bray et al. (2017) tested young adult guide dogs in a battery comprised of tests intended to measure temperament traits and problem-solving skills. Among the tests, there was a greeting test in which a stranger, hunched and draped in a cape, entered the room where the dog was and then encouraged the animal to approach in a friendly manner and patted them if they did. This could be taken as a sociability test, although the way in which the stranger entered the room might have boosted fearful responses initially. Indeed, the authors considered this test to be a measure of fear and confidence and, when performing an exploratory PCA, duration of interaction with the stranger in this test grouped with behaviour in a test in which a startling stimulus was presented (an auto-open umbrella). Interestingly, though, behaviour in the greeting test also grouped with retrieval score, a variable that reflected the willingness of the dog to play fetch with the experimenter (i.e., a potential measure of social reward). An important point to bear in mind, though, is that the ball play test was carried out immediately after the greeting test by the same person.

Similar results were obtained by Turcsán et al. (2018), who used a test battery to study personality traits in a sample of Border collies. The “greeting the experimenter” test aimed to examine the subjects’ reaction to an unfamiliar friendly human and, as such, could be considered a sociability test. Results from an EFA revealed that behaviours in this sociability test grouped together with a component from a ball play test that reflected the dogs’ playfulness (with the caregiver), implying a positive association between sociability and social reward.

In a recent study, the authors explicitly proposed that the high degree of interindividual differences found in dogs’ performances in a choice task could be related to sociability (Bolló et al., 2021). In this study, dogs could choose between two food rewards: one was in front of a video projection of the owner’s face, while the other was

in front of a projection of the back of the owner's head. At the group level, dogs displayed a preference for the food reward associated with the owner's face, but there were substantial differences between subjects. Importantly, in this study owners completed a questionnaire with five questions that intended to assess the degree to which dogs find social interactions rewarding. Some of these items referred to the dogs' tendency to establish physical contact and remain in proximity, as well as to the enjoyment of being among people, which are similar to items constituting the sociability factor in dog personality questionnaires (see Table A.2). However, when examining the association between the score in this questionnaire and the dogs' tendency to prefer the location associated with the facing owner, no significant correlation was found. The authors hypothesized that the owners or the questionnaire might not provide accurate assessments of dogs' sensitivity to social reward, and that there might be other factors causing the individual differences in the preference for the owner's face.

1.5.1.3.3. Social maintaining

The third aspect of social motivation refers to individuals' desire to maintain social interactions over prolonged periods of time (Chevallier et al., 2012). Behaviours intended to establish, maintain and enhance social relationships, so-called maintaining strategies, are included in this category. In a previous section I proposed that synchronization and conformity could serve the function of maintaining social bonds between humans and dogs. In this section I search for evidence of a link between sociability and these behaviours.

In the studies mentioned above, in which Brown (2019) explored different tasks that could be measuring sociability, dogs were presented with a synchronicity test as well. In the two studies, only a weak correlation ($r = .37$ in the second study) was found between synchronicity behaviour (i.e., proportion of trial in proximity) and behaviours in the sociability test. Although the measure of synchronicity used in this study has been included in other studies assessing dog-owner behavioural synchronization, and is considered as the "location/local synchrony" component of synchronization (Duranton et al., 2018; Duranton & Gaunet, 2016a; Pedretti et al., 2021), using only this variable as an indicator of synchronization gives limited information.

In an earlier study Hennessey et al. (2001) presented shelter dogs with a behavioural test with different phases. In one of the phases, the experimenter entered the test arena and stood quietly for 2 minutes. Then, they walked around the perimeter of the arena for 45 seconds and finally exited the area. The researchers coded the latency to contact the person and the duration of proximity and of physical contact when the human was stationary, which could be interpreted as a measure of sociability, as well as the duration of proximity while the human walked around the perimeter, which could reflect the location synchrony aspect mentioned above. All these behaviours were found to group together in the same factor.

A recent study that examined the effect of intranasally administered oxytocin in dogs' human-directed social behaviours did include multiple indicators of synchronization (Pedretti et al., 2021). This study found that post-administration oxytocin levels were associated with the duration of proximity to the owner in a behavioural synchrony test (i.e., local synchrony) and with the duration of gazing at the owner during a shared attention test. However, there was no association between oxytocin concentrations after administration and measures of activity and temporal synchrony (i.e., time spent performing the same action as the owner at the same time, and latency to switch to the same activity of the owner, respectively). In addition, dogs with higher endogenous (pre-administration) oxytocin concentrations showed less temporal synchrony (i.e., they showed a longer latency to switch to the same activity of their owners). Given that oxytocin has been associated with sociability, these findings partly contradict the hypothesis of a positive relationship between sociability and behavioural synchronization.

Although there is evidence of dogs conforming to human's choices, we know only of one attempt at examining potential associations between the tendency to conform and dogs' personalities. Turcsán et al. (2018) tested Border collies in a test battery with the aim of assessing personality traits. One of the tests of this battery was a food choice test, in which the dogs' tendency to conform to their caregiver's choices was examined. The food choice test didn't show sufficiently high loadings in an EFA, and hence didn't belong to any of the personality traits identified in the study. Recently, a study investigated the mechanisms behind dogs' social susceptibility, and found that it was increased by social stimulation and oxytocin treatment (Kis et al., 2022).

An interesting point that has been raised is that when an individual changes their behaviour in response to that of others it can be related to compliance or obedience

(Hellmer et al., 2018, 2021). In the case of studies addressing the effect of human social influence on dogs, subjects might interpret the communicative signals emitted by the human as a request or as a command. Importantly, it has been hypothesized that dogs were selected for increased submissive inclinations (*deferential behaviour hypothesis*; Range et al., 2019; see Table 1.1), and hence have a tendency to follow humans' lead. Therefore, if humans represent authority figures for dogs, it might be difficult to separate conformity from obedience (an alternative would be studying conformity to children's choices or, especially, to conspecifics).

If conformity reflects obedience, then one could also assess the link between sociability and obedience. In one study that presented dogs with a behavioural test battery, sociability and obedience variables from different subtests grouped together to form a single sociability-obedience factor (Turcsán et al., 2018). However, in most dog personality questionnaires, trainability (or “training focus”, “responsiveness to training”) emerges as a separate factor from sociability (see table A.2). A moderate positive correlation has been found between the DPQ facet “Companionability” and the “Training Focus” factor from MCPQ-R (Henriksson, 2016). In contrast, highly trained dogs were found to be less inclined to conform to their owner's choice, while for dogs with higher scores on separation-related problems in the C-BARQ questionnaire the opposite pattern emerged (Prato-Previde et al., 2008).

1.5.2. Social cognition and sociability/social motivation

In this section I will discuss how sociability and social motivation might relate to social cognition, and finally present evidence of associations between these constructs in dogs.

1.5.2.1. Potential links between sociability and social cognition

Research on animal cognition has typically focused on examination of the cognitive abilities of a species, considering performance in cognitive tasks only at the group level, with little regard to individual differences. However, in the last few years

there has been a growing interest in the study of consistent interindividual differences in animal cognition (Boogert et al., 2018; Rowe & Healy, 2014). Still, many of these studies come from the behavioural ecology field and are mainly concerned with the potential links between individual cognitive abilities and fitness (Boogert et al., 2018; Rowe & Healy, 2014), and don't examine the association between cognitive performance and other psychological characteristics, such as motivation and personality or temperament (Bray et al., 2017; Rowe & Healy, 2014). Even when associations between personality and cognition are considered (Boogert et al., 2018; Dougherty & Guillette, 2018; Griffin et al., 2015; Guillette et al., 2017), studies often address personality in a broad sense, usually analysing how bold individuals or fast explorers might differ from shy individuals or slow explorers in their performance in cognitive tasks or in their cognitive styles (Amy et al., 2012; Guenther et al., 2014; Guillette et al., 2015; F. Range et al., 2006; Sih & Del Giudice, 2012; for reviews see Carere & Locurto, 2011; Locurto, 2006). There are, nevertheless, some exceptions, especially in studies with non-human primates (for a review see Padrell et al., 2020; see also Nawroth et al., 2017 for a study examining the association between intraspecific sociability and cognitive performance in goats). Additionally, researchers commonly test general cognitive abilities, such as memory and learning, and don't specifically examine socio-cognitive abilities (but see Seyfarth & Cheney, 2015 for a summary of a series of studies linking personality with response to social challenges in baboons).

In this context, it is important to recall the *emotional reactivity hypothesis*, which establishes a connection between temperament and social cognition (Hare et al., 2005; Hare & Tomasello, 2005a, 2005b; see Table 1.1). According to this hypothesis, selection on social-emotional systems could be the basis for social cognitive evolution in animals, such as dogs, and even in humans. The authors explain that novel social problem-solving skills might have evolved as a by-product of selection on systems mediating fear and aggression. Although this hypothesis was presented in the context of comparisons between species, the authors also wondered whether individuals with particular types of temperament could possess better social problem-solving skills (Hare & Tomasello, 2005a).

In general, it has been proposed that personality might affect cognition through its mediation in the situations an individual encounters (Guillette et al., 2017; Sih & Del Giudice, 2012). For example, bolder individuals or faster explorers are more likely to

encounter new situations more quickly and might face certain situations more often than shy individuals or slow explorers. Similarly, one could hypothesize that highly sociable individuals would encounter social situations earlier and more frequently than less sociable individuals, and thus would have more opportunities for learning social abilities. Such an explanation has been put forward to address the superior performance of domestic fox kits in an OCT compared to their non-domesticated counterparts (e.g., Reid, 2009). Analogously, in the context of developmental studies of human social cognition, it has been proposed that children's social tendencies, which include behaviours affecting their access to social information (e.g., aggression, sociability, shyness), as well as their attention to said information, might be associated with their theory of mind skills (Lane & Bowman, 2021).

Moreover, it is beneficial for an individual that is more sociable and repeatedly finds itself in social contexts to acquire skills to successfully deal with these situations. This is to some extent related to the intraspecific appraisal of the social intelligence hypothesis, which predicts a positive relationship between sociality and cognition at the individual level (Ashton et al., 2018). If the social environment regulates cognitive development, and if personality, and in particular, sociability, can influence the social environment of an individual, then sociability can have an impact on cognition through the social environment. A sociable individual will face more social challenges; hence they will need to develop the adequate skills to overcome them.

Wascher et al. (2018) discuss the potential bi-directional relationships between sociality and cognition from a behavioural ecological perspective. Social relationships might affect cognitive performance through individual differences in social experiences (e.g., an animal's position in the social network can determine who they learn from and when), but cognitive abilities such as learning might also influence social relationships (e.g., an animal's success in a relevant task can affect its position in the social network). In the case of sociability and social cognition, a bi-directional relationship or positive feedback loop is also expected. A sociable animal that faces social problems often will develop the necessary skills to solve them successfully, which will lead to a positive experience that will encourage more social encounters.

Personality might also influence cognition through its effects on information use or learning strategies; that is, individuals with different personalities might differ in the type of information they prioritize when learning and making decisions. It has been

suggested that sociability might determine learning strategies, so that sociable individuals might prioritize social information/learning over private information or individual learning (Sih & Del Giudice, 2012; Trompf & Brown, 2014).

Apart from its impact on access to information and its use, personality might also interact with cognition by modifying information perception and interpretation. Findings from the human personality literature suggest that this is the case. For example, there is evidence that extraversion can bias the perception of emotional facial expressions, with extraverts being more sensitive to positive facial expressions than introverts (Knyazev et al., 2008).

1.5.2.2. Potential links between social motivation and social cognition

Individuals might not only differ from others in how they learn (i.e., social versus individual learning) but also on what they learn. The social orienting component of social motivation refers to attentional priority granted to social stimuli. While this preferential attention might favour acquisition of skills through observation (i.e., social learning) over direct experience (i.e., individual learning), another consideration is that individuals that pay more attention to social cues might have more opportunities or be better at learning social skills than individuals that are more attentive to non-social stimuli. Again, a similar argument has been made when considering possible explanations for domesticated fox kits' superior performance in OCTs compared to non-domesticated fox kits (e.g., Reid, 2009).

Interestingly, developmental studies found that direct social engagement was unrelated to theory of mind abilities in children, and it has been hypothesized that what might predict socio-cognitive development is not the tendency to socially withdraw per se, but the attention towards and interest in social interactions (Lane & Bowman, 2021). Thus, it might be important to distinguish between different types of social disengagement and to consider the role of social orienting in social cognition. For example, a child that is shy might not engage in direct social interactions but might still be interested in them, while other children might avoid social contexts because they are disinterested or anxious (Lane & Bowman, 2021). In this case, we would expect the first child to outperform the others in socio-cognitive tasks, given their higher social orienting.

Similar to what was discussed before with sociability as a personality trait, the social reward component can also act on social cognition. If an individual finds social interactions rewarding, it is expected that they will engage in them more often than others, which, again, would give them an advantage in acquiring and improving their socio-cognitive abilities. As already mentioned, this would possibly lead to a positive feedback loop. Moreover, we would expect individuals with high social motivation to learn better when they are provided with social than non-social rewards. However, this increased performance in itself could be taken as a measure of social motivation, so one should be careful to avoid circular reasoning (i.e., “Fido has a high social motivation because he learns better when given a social compared to a non-social reward, and Fido learns better when given a social reward because he has high social motivation”). On the other hand, the social reward component also refers to the preference for collaborative over individual activities. In this regard, at the species level it has been proposed that selection for prosociality could lead to superior socio-cognitive abilities (Hare, 2017). Apart from that, and similarly to what was mentioned above, possessing these abilities would be beneficial to an individual that regularly finds itself in collaborative contexts.

Finally, let us consider the potential links between the social maintaining component and social cognition. This component reflects the desire to maintain social bonds for prolonged periods of time and is manifested in behaviours that aim to establish, maintain and enhance social relationships. Thus, it is evident that an individual that has a strong motivation to maintain social bonds will invest more in learning the necessary skills to keep them. On the other hand, social motivation might not only determine the acquisition and development of socio-cognitive abilities but might also affect their expression. In this regard, Contreras-Huerta et al. (2020) discussed how effort and reward sensitivity can modulate performance in social tasks. If performing a socio-cognitive task is effortful, an individual that shows low success might not necessarily lack the necessary skills; rather, they might well not be sufficiently motivated to use them.

Lastly, it is worth mentioning that the link between social motivation and social cognition is precisely the central element of the social motivation theory of autism, which is the context in which the conceptual model of social motivation we have used in our project was presented (Chevallier et al., 2012). This hypothesis posits that deficits in socio-cognitive skills are a consequence of reduced social motivation in persons with ASD (but see Jaswal & Akhtar, 2019 for a challenging view).

1.5.2.3. Empirical evidence of associations between social motivation/sociability and social cognition in dogs

In dogs, few studies have taken an explicit individual-level approach in the topic of cognition (Arden et al., 2016; Bensky et al., 2013). Some studies have examined the relationship between personality or temperamental traits and cognition or have recognized the potential role of personality traits and motivational factors in problem solving (Bray et al., 2015, 2017; Fugazza et al., 2022; Sarah Marshall-Pescini et al., 2008; Sarah Marshall-Pescini, Virányi, et al., 2017; Passalacqua et al., 2013; Udell et al., 2014). Relatedly, the *dependence hypothesis* might imply that an elevated social motivation can impair dogs' independent problem-solving skills (Udell, 2015). Interestingly, some have argued against the separation of temperament and cognition, especially in view of results of a structural analysis of a battery of tasks typically used to measure temperament and problem-solving, which highlighted the complex interplay between the two (Bray et al., 2017).

Here, I will focus on studies that might be informative regarding the link between sociability/social motivation and social cognition specifically. In our research project we are particularly interested in two aspects: understanding of communicative cues and sensitivity to visual attention. Thus, the search for empirical evidence is primarily focused on studies investigating associations between dogs' social motivation and/or sociability and their performance in tasks measuring these specific socio-cognitive abilities in their interaction with humans.

In their discussion of the *emotional reactivity hypothesis*, Á. Miklósi & Topál (2005) addressed the possibility of a relationship between emotional reactivity and socio-cognitive abilities at the individual level. Based on their observations they claimed that there is no association between dogs' aggressiveness/friendliness and their performance at a "cueing test" (J. Vas, unpublished data). Gácsi, Györi, et al. (2009) tested wolves and dogs' performance in a two-object choice test at different ages and with various human gestures. They didn't find any association between the animals' duration of struggling when being handled (a behavioural indicator of reactivity and emotionality) and their success at the task. In the case of adult wolves, however, a lower latency to establish eye

contact (i.e., higher social orienting) with the experimenter during the task was associated with a higher success. In addition, wolves of 8 weeks and of 4 months that struggled more showed a longer latency to eye contact. In general, dogs had lower values and lower variability in these variables than wolves (i.e., they were generally fast to establish eye contact and struggled shortly), which could explain the lack of correlations in some cases.

In their dog cognition test battery, E. L. MacLean et al. (2017) included OCTs in which different gestures were used to indicate the baited container (pointing, gazing, reaching), as well as a social referencing test and an unsolvable task, which measured the dogs' tendency to gaze at a human's face when social play was interrupted, and to seek social help, respectively. As discussed earlier, these tests could be taken as measures of social motivation. In a factor analysis with varimax rotation, the social motivation and the social cognition (OCTs) tests loaded onto different factors. Given that the varimax rotation generates orthogonal (i.e., non-correlated) factors, this result doesn't support an association between measures of social cognition and of social motivation.

In their study, Sundman et al. (2018) provide a direct assessment of the relationship between performance in a pointing test and human-directed social behaviour in an unsolvable task in Labradors (common type and field type) and German Shepherds. In the framework of the present work, performance in the pointing test is a measure of social cognition, while human-directed social behaviours in the unsolvable task reflect social motivation (specifically, social orienting). The authors, however, framed these behaviours (i.e., following human gestures and seeking human contact) as two communicative skills and they hypothesized that they could "reflect a common underlying general ability for interacting with humans" (Sundman et al., 2018; p. 47) or a "common sociability with humans" (p. 51) and speculated that they could be "genetically correlated traits evolving during domestication" (p. 47). Given that they found no positive correlations between performance in the pointing task and components derived from behaviours in the unsolvable task, they concluded that these tests examine aspects of human-directed social behaviour that were selected independently. Similar results were obtained by Lazarowski et al. (2020), who presented pet and detection dogs with an OCT and an unsolvable task, and also failed to find any significant correlation between accuracy on the OCT and human-directed behaviours in the unsolvable task. The researchers brought up the point that behaviours in the unsolvable task might be more

related to persistence (see also Lazzaroni, Marshall-Pescini, et al., 2020), and concluded that the tasks measured different aspects of social cognition.

Unexpectedly, Sundman et al. (2018) found a negative correlation between performance in the pointing task and the Owner Contact component (which reflected proximity to and physical contact with the owner during the unsolvable task) in the case of common-type Labradors. The authors suggested as a possible explanation that dogs showing higher Owner Contact could be less willing to leave their owner and follow a stranger-provided cue in the pointing test but discarded it in consideration of the high levels of sociability towards strangers in common Labradors. Hence, confusingly, the results of this study hint at a potential negative correlation between socio-cognitive abilities and social motivation in some dogs.

Brown (2019) conducted three studies in which the association between performance in a pointing test and potential sociability/social motivation measures was examined. In the first two studies, the cue given was a dynamic momentary proximal pointing (i.e., the cue was enacted in view of the subject but was withdrawn before the subject could choose, and the tip of the finger was close to the container). In the first study, success in the pointing test showed a weak positive correlation ($r = .37$) with the reinforcer efficacy of petting and verbal praise (i.e., social reward), and an unexpected very weak negative correlation ($r = -.19$) with proximity in the sociability test. In a PCA, the pointing and the reinforcer efficacy tests grouped together, which the researcher related to their potential link with learning propensity. In the second study, in contrast, there was no correlation between the pointing test and reinforcer efficacy, and the correlation with sociability was weak and negative. In this study, a reunion test was introduced, which also showed weak negative correlations with success in the pointing test. The correlation matrix showed that the correlation between synchronicity and the pointing test was weak and positive. Finally, in the third study a dynamic continuous distal pointing gesture was used (i.e., the cue was not withdrawn before the subject could choose, but the tip of the finger was far from the container) and only the correlation with the reinforcer efficacy test (and landmark tests) was examined. There was a weak negative correlation between performances in the pointing and in the reinforcer efficacy tests ($r = -.27, p = .19$). When dividing the subjects into a low and a high sociability group based on their number of palm touches in the reinforcer efficacy test (i.e., in the present work: low and high social reward), no significant difference was found between groups in their

success in the pointing test (although high sociability dogs made fewer correct choices). Therefore, this set of studies provides contradicting evidence of the existence and direction of the association between sociability/social motivation and social cognition.

A point that was raised earlier is that personality might affect cognition through its influence on the situations an individual encounters. That is, sociability might affect social cognition through its influence on an individual's social experiences. In this sense, it is important to consider whether and how dogs' socio-cognitive abilities are associated with their social experiences. The relative contribution of domestication and ontogeny to dogs' social cognition has been a topic of discussion (e.g., Hare et al., 2010 vs Udell et al., 2008; Hare & Tomasello, 2005 vs Á. Miklósi & Topál, 2005; Riedel et al., 2008 vs Wynne et al., 2008), and commonly the “*domestication hypothesis*” (*selection for communication hypothesis*) is confronted with the *Two Stage hypothesis* (see Table 1.1). Results showing that dogs can successfully follow human communicative signals from a young age, before receiving substantial experience with humans and with little evidence of learning (Bray et al., 2020, 2021; but see Dorey et al., 2010; Wynne et al., 2008) suggest that dogs' socio-cognitive skills might be biologically prepared (*sensu* Cummins & Cummins, 1999). This would mean that dogs can learn these skills early because they possess a biological bias or predisposition to focus their attention on human communicative cues (e.g., selection for attention towards the human face in some hypotheses).

However, this bias could be dependent on the social motivation of the individual, which in turn could be related to their sociability. As already stated, individual differences in sociability in dogs have been associated with gaze duration at the human face (Jakovcevic et al., 2012; Putrino et al., 2014). These findings indicate that highly sociable animals might remain attentive to humans for longer durations than less sociable individuals, which could be useful for learning social cues (Putrino et al., 2014). Furthermore, sociability modulates biological motion preference in dogs, and biological motion sensitivity has been proposed as a marker of social cognition in dogs (Ishikawa et al., 2018), as previously done in humans (Pavlova, 2012).

The potential biological preparedness of dogs' socio-cognitive abilities does not mean that these skills are unaffected by the environment (Cunningham & Ramos, 2014). It has been claimed that exposure to the human social environment is the most relevant variable when studying dogs' responsiveness to human social cues (Zaine et al., 2015; for

a review of the influence of level of human experience in the performance of non-human primates and dogs in OCTs see Clark et al., 2019). Gácsi, Kara, et al. (2009) investigated the effect that exposure to social experiences and specific communicative interactions had on performance in a point-following task in pet dogs. In order to do this, they asked owners whether the dog was kept inside or outside the house (i.e., keeping condition), whether they spent less or more than 1 hour daily in active interaction with their dog (which included playing, training, walking) and whether their dog rarely or often initiated communication with them (which included vocalizations, gaze alternations, nudging and catching hand/cloth). For my purposes, the two latter questions could be related to the dogs' social motivation. The researchers failed to find any significant association between these factors and dogs' success in the pointing task and concluded that after the age of 2-4 months environmental influences might not play an important role on dogs' ability to use human pointing gestures. Interestingly, however, they suggested that "task-relevant cognitive abilities can be shaded/masked by species-specific characteristics (or individual "temperament/personality" traits)" (Gácsi, Kara, et al., 2009; p. 479) and mentioned the potential influence of dogs' tendency to pay attention to humans (i.e., social orienting).

A source of evidence that dogs' experiences are associated with their performance in social cognition tasks (*Two Stage hypothesis*; see Table 1.1) can be found in comparisons between different dog populations. For example, when comparing shelter dogs and research dogs with pet dogs, which differ in their level of interaction with humans, some studies have showed that shelter and kennel-reared dogs have poorer performance in tasks involving following a relatively complex human cue (momentary distal pointing) and discrimination of the attentional state of humans in some situations (D'Aniello et al., 2017; Lazarowski & Dorman, 2015; Osborne & Mulcahy, 2019; Udell, Dorey, et al., 2008; for reviews see Duranton & Gaunet, 2016b; Jarvis & Hall, 2020).

On the other hand, compared to pet dogs, shelter dogs have a higher tendency to gaze and remain in proximity to humans in various contexts (problem-solving task: Barrera et al., 2015; sociability test: Barrera et al., 2010; but see Shin & Shin, 2017), and social contact might act as a stronger reinforcer for them (Feuerbacher & Wynne, 2014), which would suggest a potentially higher social motivation (Barrera et al., 2015; Gácsi et al., 2001). If social motivation is increased in shelter dogs, one might expect them to possess higher socio-cognitive skills, as discussed above. However, this increased social

motivation needs to be accompanied by opportunities to learn or to practice how to use human social cues.

Given shelter dogs limited social opportunities, it is unsurprising that this presumed elevated social motivation doesn't lead to better socio-cognitive abilities in shelter dogs. Sociability and/or social motivation can't have an effect on the acquisition of socio-cognitive abilities if the subject has no control over the social environment, or more specifically, over their social interactions. When provided with additional training, shelter dogs can learn to use a human gesture they had previously failed to use (Udell et al., 2010a). Younger shelter pups outperformed older in following certain human gestures probably due to differences between the groups regarding their experience of living in human homes (more dogs from the young group were fostered or had been surrendered by an owner rather than being strays) (Zaine et al., 2015). This study also found a positive correlation between experience living in human homes and success in following the most difficult human gestures. More recently, it was shown that shelter dogs that received enriched human exposure improved their success in a point-following test, surpassing control shelter dogs and reaching an identical performance to pet dogs within 7 weeks (Jarvis & Hall, 2020). Surprisingly, somewhat similar results were found in free-ranging dogs, with a study showing that brief exposures to positive social interactions (petting) increased the likelihood of following a pointing cue (Bhattacharjee & Bhadra, 2022). Taken together, these results highlight again the relevance of dogs' previous social experiences in their performance in object choice tasks assessing human gesture comprehension. Finally, similar conclusions have been derived from studies evaluating the effect of training, which suggest that it is specifically the type of training that might be relevant in the development of this socio-cognitive skill (reviewed in Bensky et al., 2013).

Another way in which sociability/social motivation could be related to performance in gesture comprehension tests is through its interaction with the identity of the cue provider (e.g., see Cunningham & Ramos, 2014; Elgier et al., 2009; Horn et al., 2013). For example, more sociable dogs might be more willing to follow a cue provided by an unfamiliar human. Individuals with the highest social motivation levels might not only pay more attention to social cues compared to non-social cues but might show a higher tendency to attend to social cues regardless of the identity of the provider (i.e., show less discrimination).

Compared with the large number of studies assessing dogs' comprehension of human gestures, fewer studies have examined dogs' sensitivity to humans' visual attention (for a review see Huber & Lonardo, 2023), and to my knowledge none have tried to analyse its association with personality traits and/or motivational factors. E. L. MacLean et al. (2017) included what they named a "perspective-taking" task in their test battery, which measured the dogs' tendency to obey a command depending on whether the experimenter was watching them or had their back towards them. However, the variable was not suitable for factor analysis and was discarded.

On the other hand, authors have also noted the role of life experiences in dogs' ability to recognize human attentional cues. For example, when testing pet dogs, shelter dogs and wolves, Udell et al. (2011) found that their success varied depending on the type of occluder (i.e., book, bucket, camera) blocking the human's visual attention, which they related to the different environments and experiences encountered by each group. As discussed above, sociability and social motivation can modulate the experiences of individuals and thus affect their acquisition of socio-cognitive skills, and in particular, their discrimination of human's attentional states and their understanding of their visual fields.

Finally, it is worth mentioning that potential associations between sociability and humans' attentional state discrimination were examined in foxes in captivity (Jesica Fagnani et al., 2017). Foxes were divided into a high and a low sociability group, based on whether they approached an experimenter (separated by a fence) within 50 cm. When presented with a test in which subjects could choose between two food containers which were located in front of a facing and a non-facing human, respectively, sociability levels didn't explain the animals' capacity for detection of visual attention, since subjects from both groups discriminated between the containers. Sociability did, however, modulate subjects' choices, with foxes from the low sociability group preferring to approach the container in front of the non-facing experimenter or not making a choice.

Overall, the association between sociability/social motivation and social cognition is far from clear. So far, it seems that studies directly examining correlations between behavioural measures of sociability/social motivation and performance in socio-cognitive tasks have failed to find a correlation or have even found a correlation in an unexpected direction. What seems more evident is that life experiences influence dogs' socio-cognitive skills.

1.6. COMPARATIVE APPROACH: THE DOG AS A MODEL SYSTEM

The comparative approach aims to gain a better understanding of a behaviour or cognitive ability by comparing individuals from different species. Addressing the study of a behaviour or cognitive ability from a comparative perspective facilitates the understanding of its ultimate causes, which include its evolutionary origin (i.e., the selective pressures that shaped it), as well as its adaptive value or function (i.e., how it increases fitness). At the same time, the comparative approach provides us with a wider perspective regarding the proximate causes, that is, the potential underlying mechanisms (i.e., internal processes and external stimuli) and developmental processes (i.e., ontogenetic origin and changes) involved (Enikő Kubinyi, 2006; Á. Miklósi et al., 2004; Smith et al., 2018).

In the last decades, the dog (*Canis familiaris*) has become a very productive model system to study the evolution of social behaviour and cognition. Indeed, in a more anthropocentric version of the comparative approach, dogs have been frequently proposed as a model to understand the evolution of human social behaviour and cognition (Ádám Miklósi et al., 2007; Topál et al., 2009), or even human social disorders (e.g., Persson et al., 2016; József Topál et al., 2019). In this section I briefly argue that dogs might be an especially suitable model to study social motivation in general, and due to their evolutionary history, which is closely linked to humans, they might be particularly informative for throwing light on the evolution of human social motivation.

As mentioned earlier, the *human self-domestication hypothesis* (HSD) establishes a correspondence between human evolution and domestication by proposing that humans, like domestic species, experienced a selection for prosociality (understood as positive social interactions) and against aggression, that led to the emergence of a suite of correlated traits at the anatomical, physiological, behavioural and cognitive level (i.e. the DS) (Hare, 2017). In this sense, comparisons between wolves and dogs highlighting differences in their aggression, social motivation, social cognition, as well as their physiology and morphology, that are similar to differences between Holocene and Lower Palaeolithic humans, have been used as evidence in support of the domestication syndrome in modern humans. Relatedly, the *emotional reactivity hypothesis* defends that selection for a decrease in emotional reactivity results in an increase in social tolerance that enables the emergence of complex levels of cooperative communication, a process

that might have happened in both humans and dogs (Hare & Tomasello, 2005b). Nevertheless, it is important to mention that the applicability of these hypotheses to dogs has been questioned, particularly in view of accumulating knowledge regarding dogs and wolves' social ecologies and abilities that contradicts assumptions made by these hypotheses, such as the existence of a general decrease in aggression and increase in social tolerance, as well as of superior socio-cognitive abilities in dogs (e.g., Friederike Range & Marshall-Pescini, 2022b). In fact, some authors have underscored that human social evolution could be more similar to that of wolves, given the intragroup prosocial tendencies so prominent in both species (e.g., Shilton et al., 2020).

Notwithstanding the above, importantly dogs were the first domesticated species and have lived in close association with humans for thousands of years. Comparative studies have often focused on non-human primates, searching for homologies given their close phylogenetic relationship with humans. However, species that share similar environmental conditions can evolve similar behavioural traits (i.e., analogies) through convergence, even if they are phylogenetically distant. Having shared a niche with humans for an extended period of time, dogs might have experienced evolutionary convergence with humans, leading to the emergence of behaviours in dogs that are functionally analogous to human behaviours (Á. Miklósi et al., 2004; Ádám Miklósi et al., 2007). Whether these were consciously exerted by humans or not, it seems undisputable that dogs have experienced selective pressures for their adaptation to life with humans, which presumably favoured behaviours and cognitive abilities that eased their interactions with us. This has been particularly emphasized in the study of the evolution of socio-cognitive skills (e.g., Cooper et al., 2003; Á. Miklósi et al., 2004), but has also been discussed with regards to social behaviour in general. For example, Topál et al. (2009) proposed that the divergence of dogs from wolves involved an increase in sociality, cooperativeness and communicability in the anthropogenic environment, that is analogous to changes occurring during hominization.

As discussed earlier, adaptational changes to dogs' behaviour during domestication likely included an intensification of their interest for social interactions with humans. Similarly to humans, dogs have been claimed to possess an hypertrophied social motivation (*the hypersociability hypothesis*; vonHoldt et al., 2017). Some authors have explicitly proposed that the motivation system that regulates human-directed social behaviour in dogs, not only is key in the development of dogs' human-like social

competence, but might constitute a functional analogue of the human social-affiliative motivation system (Topál et al., 2019). Interestingly, the genetic basis for dogs' hypersociability is found in structural variants of genes associated with Williams-Beuren syndrome in humans, a disorder characterized by hypersocial behaviour, among other symptoms (vonHoldt et al., 2017). This raises the possibility that some social behaviours in dogs are not only functionally analogue to those of humans but also share a similar mechanistic basis (see also Persson et al., 2016).

Overall, it seems clear that dogs are a particularly interesting model species to study the social motivation construct. The behavioural, cognitive and motivational traits of dogs have been shaped during domestication. Social motivation towards humans has repeatedly emerged as a key trait in discussions regarding dog domestication. Domestication is an evolutionary process that involves adaptation to an anthropogenic environment. Sharing a niche can lead to evolutionary convergence between distantly related species. Hence, convergent traits might have evolved in dogs and humans, including a functionally analogue social motivation system. Moreover, human evolution might have involved a self-domestication process. Thus, although studying social motivation in dogs is valuable in its own right, it might also provide us with a better understanding of our species.

1.7. OBJECTIVES & HYPOTHESES

The overall goal of the study to be reported here was twofold. The main objective was assessing and testing several hypotheses regarding human-oriented social motivation, sociability and social cognition in the domestic dog through the use of a battery of experimental tasks and an abridged version of a standard dog personality questionnaire. The secondary goal was exploring whether the study subjects could somehow be classified into profile types or classes based on their scores on the studied behavioural measures of social motivation and sociability. In what follows I will describe the hypotheses and derived predictions that we set out to test in the present work and provide an overview of the theoretical and conceptual background that guided them.

Tameness is one of the central features of the domestic phenotype or domestication syndrome (DS). Apart from fear of and reactive aggression towards humans, human-

directed social motivation, that is, a propensity to seek proximity and engage socially with humans, might have been a primary target of artificial selection or, alternatively, a side effect of the domestication process. In dogs specifically, human-oriented social motivation has been hypothesized to be a fundamental target of selection during domestication (e.g., *two behavioural tendencies hypothesis*, *the hypersociability hypothesis*; see Table 1.1). A more elaborated conceptualization and evaluation of the social motivation construct can therefore be valuable for gaining a better understanding of the changes that dogs and their ancestors have undergone during the domestication process, which set them apart from wolves and which might also have taken place in humans in their own evolutionary history (*human self-domestication hypothesis*; Hare, 2017). In order to do this, we adopted as a working strategy the conceptual framework of social motivation devised by Chevallier et al. (2012). However, it is important to clarify how this conceptualization relates to sociability in a narrow sense, i.e., the tendency to approach and interact with unfamiliar humans in a positive manner, and in a broad sense, i.e., as a personality trait. One possibility is that in the initial stages of domestication, sociability in its narrow sense was a direct target of selection and this brought about a cascade of changes in the dogs' human-directed social motivational system. In addition, the DS involves changes at the cognitive level. More specifically, compared to their wild counterparts, domestic species are expected to possess superior interspecific socio-cognitive abilities that would facilitate their interactions with humans. Importantly, if heightened social motivation and complex social cognition are DS traits, they should be intercorrelated.

Hence, the main objective of this project was to assess social motivation, a potential key element in dog domestication and human evolution, and its possible associations with sociability and social cognition. Different behavioural manifestations of social motivation towards humans were studied in the domestic dog, tentatively organized around three categories (social orienting, reward and maintaining), as well as their relationship with sociability (measured through a behaviour test and a personality questionnaire) and with performance in socio-cognitive tests. This major part of the project thus had three goals: 1) studying the association between the hypothesised behavioural manifestations of social motivation, 2) evaluating the relationship between sociability and these manifestations of social motivation, and 3) determining if individual differences in sociability and/or in social motivation are associated with variation in the

dogs' socio-cognitive abilities. Our research aimed to test the following three general hypotheses.

1.7.1. Hypothesis 1: behavioural manifestations of social motivation

The *first hypothesis* posits that the three categories of social motivation, i.e., social orienting, reward, and maintaining, proposed by Chevallier et al. (2012) in humans, can be supported empirically in dogs, and that they indeed represent behavioural manifestations of the same construct. Therefore, we tentatively predicted that a structural analysis of dogs' behavioural responses in the social motivation tests would yield a three-factor solution that would match the three categories of the conceptual model. A more relaxed and perhaps realistic version of this hypothesis was that the individuals' behaviours in the various social motivation-related tests would be positively correlated and potentially yield some kind of factor structure (not necessarily one of three components). We thought that the scheme of three components of social motivation explored here, following Chevallier et al. (2012), could be useful for studying social motivation towards humans in the domestic dog. Working with these components allowed us to consider social behaviours that could reflect social motivation, by looking for behaviours that fit the definitions of each component and the paradigms that have been used to examine them (see also József Topál et al., 2019).

Since our starting point when designing the study was the working model of the three components of social motivation, we decided to propose a specific hypothesis to test if our data fit this model. Conversely, we could have made no assumptions about the factor structure of the data and perform an exploratory analysis. In any case, this study is, in essence, an exploratory work in which what is most relevant is to generate empirical information about different human-directed social behaviours in domestic dogs, as well as the possible association between them.

So far, there is limited evidence of the association between putative behavioural indicators of human-oriented social motivation in dogs (see section 1.2.3). In a factor analysis, a social referencing task that measured dogs' tendency to gaze at a human when social play was interrupted grouped together with an unsolvable task, which assessed the animal's tendency to seek social help (E. L. MacLean et al., 2017). Positive correlations

have been found between efficacy of social reinforcers and behaviours in a reunion test (Brown, 2019). Oxytocin administration influenced both the duration of proximity in a synchrony test and the gaze duration in a shared attention test (Pedretti et al., 2021).

1.7.2. Hypothesis 2: associations between social motivation and sociability

The *second hypothesis* states that there is a positive association between social motivation and sociability. The empirical prediction tested was that the behavioural manifestations of social motivation would be positively correlated with levels of sociability, measured through a behavioural test (i.e., narrow sense) and through a personality questionnaire (i.e., broad sense).

We have separated social behaviours taken as manifestations of social motivation from a common operationalization of sociability, which consists in approaching and interacting with an unfamiliar individual (i.e., narrow sense sociability). According to this operational definition, we considered that the construct of social motivation would be broader than that of sociability and would include different social behaviours expressed in different contexts. It is entirely possible that, rather than being separate constructs, sociability could be another element within the social motivation construct. Indeed, sociability could be regarded as an additional operationalization of the social motivation construct, just like the other social behaviours we have measured, and an attempt could be made to fit it into one of the three components.

An alternative approach could have involved dropping the term “social motivation” altogether and using only the term “sociability”, which would represent a personality trait. As such, it would reflect consistent individual differences in behaviour across different contexts and across time (e.g., Stamps & Groothuis, 2010). It could be argued that the different behavioural tests we have included in each social motivation category, plus the sociability test, are all measures of a single personality trait, namely, sociability. However, another characteristic of personality traits that we didn’t tackle in our study is temporal consistency. Since we are measuring correlations of individual differences in behaviours across contexts only (*sensu* Stamps & Groothuis, 2010) but not across time, it might be the case that we were in fact studying a behavioural syndrome instead of a personality trait (Sih et al., 2004; Stamps & Groothuis, 2010). In any case,

we also attempted to assess sociability as a personality trait via a questionnaire. If we hypothesize that they are measuring one and the same construct, then a possible alternative interpretation is that by exploring the associations between the social motivation tests, the sociability test and the questionnaire, the analysis could be a sort of verification of convergent validity (e.g., see Brown, 2019).

In sum, we thought that separating what has often been defined as sociability from other social behaviours that may indicate social motivation and checking how they relate to each other would be worthwhile. The question that we had in mind when separating these constructs was: what are the psychological differences between high-sociability (i.e., individuals showing a high tendency to approach and interact with an unfamiliar human) and low-sociability individuals? For example, do highly sociable individuals show an attentional bias towards social stimuli? Do they find social interactions more rewarding than less sociable individuals? Do they express behaviours intended to maintain social bonds with a higher frequency or intensity? Intuitively, one would expect a positive answer to these questions, but we wanted to pursue this empirically.

In this regard, findings in the literature are mixed, with some studies revealing an association between proxies of dogs' sociability and hypothesized behavioural manifestations of human-oriented social motivation and others failing to do so (see section 1.5.1.3). Sociability levels have been found to influence looking patterns towards human point-light displays (Ishikawa et al., 2018). A social stimulus was more distracting than a non-social one for dogs with higher social competence (which likely involves higher sociability) (Galambos et al., 2021). More sociable dogs gaze at humans for longer durations when food is out of reach and persist longer at this behaviour during extinction (Jakovcevic et al., 2012; Putrino et al., 2014). Sociability has been found to correlate with reinforcer efficacy of petting and vocal praise and with behaviours during a reunion test (Brown, 2019). Behaviours in greeting tests with a stranger grouped together with behaviours related to playfulness (Bray et al., 2017; Turcsán et al., 2018). There is some evidence of a link between sociability and the location aspect of synchronization (Brown, 2019; Hennessy et al., 2001).

1.7.3. Hypothesis 3: associations of social motivation and sociability with social cognition

The *third hypothesis* holds that there is a positive association between social motivation/sociability and social cognition. The empirical prediction tested was that performance in the socio-cognitive tests would be positively correlated with the different behavioural manifestations of social motivation as well as with sociability.

According to the DS hypothesis, as well as the *emotional reactivity hypothesis* (and the *social motivation hypothesis* of Chevallier et al., 2012), there should be a positive correlation between social motivation and socio-cognitive skills. Additionally, as mentioned earlier, we can expect a positive feedback loop between sociability and social cognition, i.e., individuals who engage more frequently in social interactions with humans have more opportunities to learn socio-cognitive skills, which in turn make them more capable of engaging further in social interactions in a positive way. Furthermore, specific components of social motivation might be relevant to the development of social cognition or performance on socio-cognitive tasks, as discussed above.

There are mixed findings in the literature regarding this hypothesis, with most studies suggesting a negative or no association between dogs' interspecific socio-cognitive skills and indicators of human-oriented sociability/social motivation (see section 1.5.2.3). In support of the present hypothesis, success in a pointing test was correlated with the reinforcer efficacy of petting and verbal praise in one study, but this finding was not replicated in subsequent studies (Brown, 2019). Still, there is evidence that dogs' social experiences are relevant for their performance in tasks assessing human gesture comprehension and their ability to recognize human attentional cues (Bhattacharjee & Bhadra, 2022; Jarvis & Hall, 2020; Udell et al., 2010a; Zaine et al., 2015).

1.7.4. Exploration of social motivation and sociability-related clusters

As mentioned earlier, a secondary goal of the project was exploring whether dogs in our sample could be clustered on the basis of their behavioural responses in the experimental tasks that assessed their social motivation and sociability, always human-

oriented. Here we had no a priori hypothesis to test. We rather intended to ascertain if there were classes of individuals and, if so, which behavioural profiles contributed to their discrimination.

Our previous hypotheses have assumed that we would find behavioural consistency across contexts, i.e., individuals' behaviours in the different experimental tests would be correlated. Yet, at the same time, it might be important to assess contextual plasticity, that is, the degree to which an individual's behaviour, relative to the scores of others, is context-specific (Stamps & Groothuis, 2010). Selection during domestication might have reduced contextual plasticity with regards to social motivation and sociability. Alternatively, it is conceivable that while an individual displays a relatively high social motivation in several contexts (low contextual plasticity), another individual shows a relatively high social motivation in one context but a low social motivation in another (high contextual plasticity). It has also been proposed that individuals can vary with regards to the consistency in their personality expression (Fratkin et al., 2013).

To put it another way, the hypotheses described above were based on a variable-oriented approach, which reveals patterns of between-individual differences (rank-order differences) at the population level (see Uher, 2011). A complementary approach is the individual-oriented perspective, which studies the individual configurations of differential scores on multiple variables. In other words, this approach focuses on the behavioural profiles of the individuals, i.e., their differential behavioural scores across experimental tests. This approach can be used to identify groups of similar individuals based on their distinct profile shapes. Cluster analysis has been previously used to classify dog breeds according to behavioural traits (Bradshaw & Goodwin, 1999; Hart & Hart, 1985), as well as individual dogs according to their attachment-related behaviours (Topál et al., 1998), their play behaviours (Tóth et al., 2008) and their engagement in problematic behaviours (Ben-Michael et al., 1997).

CHAPTER 2 - MATERIALS AND METHODS

The sample consisted of pet dogs, which were recruited from individuals, by word of mouth and through social networks. Participants were also recruited among the students of one of the thesis' advisors, Professor Fernando Colmenares, and of the PhD candidate. The study consisted of a battery of 11 behavioural tests, which were carried out on two sessions that took place in separate days in the caregivers' homes. In addition, caregivers filled out a questionnaire that evaluated a set of personality traits and behaviours that could apply to their dog.

The inclusion criteria comprised characteristics of both the subjects and the homes. Dogs with vision or hearing impairments were excluded. Dogs also had to be at least one year old to participate, since it has been observed that personality consistency in general is higher in adults, and sociability consistency estimates in pups were not significantly different from zero (Fratkin et al., 2013). In addition, large changes in behaviours related to communication and social motivation from early ontogeny to young adulthood have been observed in dogs (Bray et al., 2020b). Only residents in the Community of Madrid that could offer a space of approximately 3 x 2 meters could participate.

Given that the procedures were non-invasive and dog subjects were never forced to participate, an authorization from the Animal Experimentation Committee of the University was not necessary. The caregivers gave their consent to participate, and the current data protection legislation was followed. A 5€ incentive was offered for completing the two sessions of the study with one dog, except in the case of Professor Fernando Colmenares' students, who were offered extra course credits for participating in the study as well as for getting participants. The latter were offered a research seminar after completing the data collection so that they could learn about the study's theoretical foundations and objectives.

2.1. SUBJECTS

A total of 104 dogs participated in the study, out of which 53 (51%) were male (neutered: 34, intact: 19) and 51 (49%) female (spayed: 41, intact: 10). The mean age was 5.7 years ($SD = 3.3$; range: 1-14); for 30 dogs (29%) the age indicated by the caregiver was an estimation. Fifty-one dogs (49%) were classified by their caregivers as purebreds and 53 (51%) as mongrels. Most dogs had lived with the current family for years at the moment of enrolling in the study, with 2 months being the shortest time of belonging to the family. Three dogs were not tested in the second session due to the impossibility of scheduling an appointment with their caregivers.

2.2. DESIGN

In order to examine the potential different behavioural manifestations of social motivation, as well as sociability and social cognition, a behavioural test battery was used. The battery consisted of 11 tests, which were always run in the same order. Although performing the tests in the same order with all the subjects does not allow to remove potential order effects, it makes comparison between individuals possible (e.g., Bray et al., 2017; E. L. MacLean et al., 2017; Turcsán et al., 2018). The tests were spread out over two sessions which were carried out on separate days, with the inter-session period being variable due to circumstances such as the caregiver's availability and restrictions derived from the public health alarm situation (SARS-Cov2 pandemic). The mean inter-session period was 16.2 days ($SD = 10.6$; range = 1-67). In the first session six tests were performed, and in the second session the remaining five (see Table 2.1), with an approximate duration of 60-75 minutes per session.

Table 2.1*Presentation order of the tests in the two sessions of the study*

Session 1	Session 2
Sociability	Object choice task – gazing
Call – trial 1	Play
Eye contact	Separation episode 3
Call – trial 2	Synchronization
Separation episode 1	Food begging
Call – trial 3	Separation episode 4
Unsolvable task	Conformity
Call – trial 4	-
Object choice task – pointing	-
Call – trial 5	-
Separation episode 2	-
Call – trial 6	-

For the evaluation of the different behavioural manifestations of social motivation, we employed and adapted protocols that had previously been used for the study of a variety of social behaviours in the domestic dog (see Figure 2.1). To evaluate *social orientation*, the eye contact (Putrino et al., 2014) and the unsolvable task tests (e.g., Passalacqua et al., 2011) were used. To evaluate the *social reward* category, protocols that assess the preference for social over non-social rewards (P. F. Cook et al., 2016) and of social over individual play (E. MacLean & Hare, 2013) were adapted. The category of *social maintaining* was evaluated through protocols designed to study dog-caregiver behavioural synchronization (Duranton, Bedossa, et al., 2017) and dog-human conformity (e.g., Prato-Previde et al., 2008).

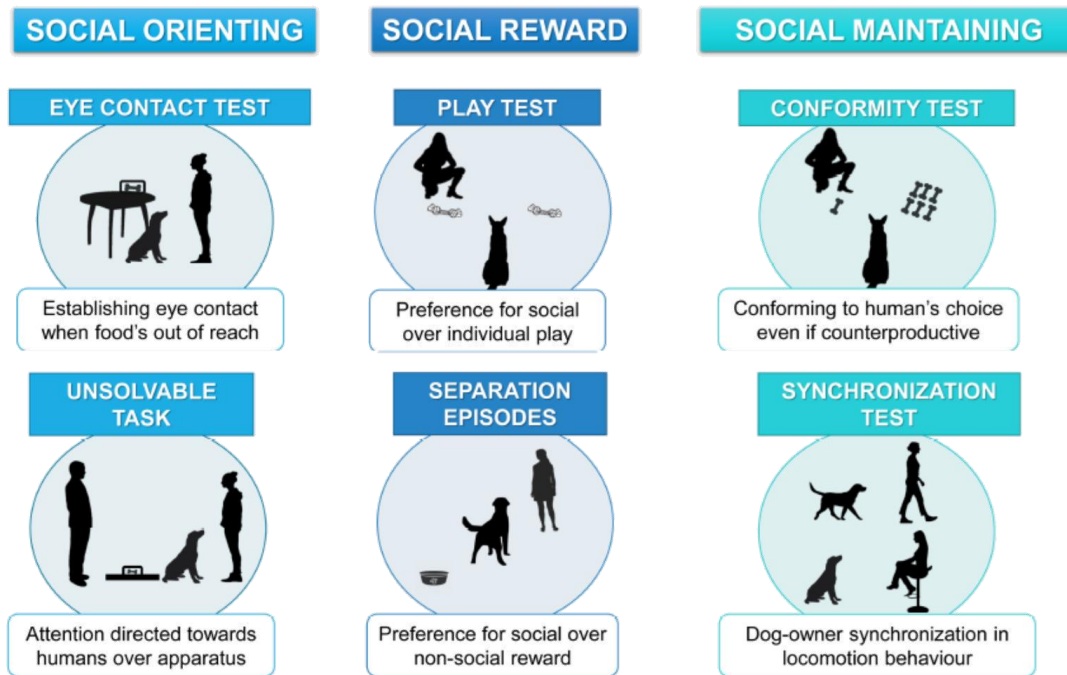
The protocol to evaluate *sociability* was one commonly used in dogs (Jakovcevic et al., 2012). We intended to complement this test with the information obtained through a questionnaire derived from the Dog Personality Questionnaire (DPQ) (Amanda Claire

Jones, 2008), which consisted of 34 items that reflect a series of adjectives and behavioural descriptions (Figure 2.2).

For the evaluation of *social cognition* standard paradigms which assess the understanding of human communicative signals in non-human species were used (e.g., Duranton, Range, et al., 2017; Á. Miklósi et al., 1998), as well as variations of some paradigms employed to analyse sensitivity to cues related to visual attention (e.g., Gácsi et al., 2004) (Figure 2.2).

Figure 2.1

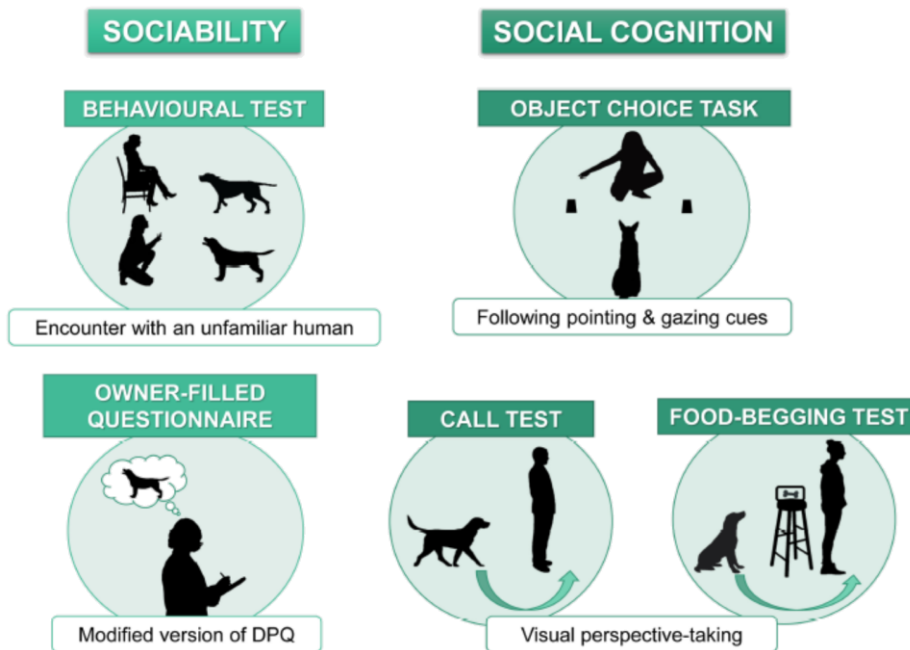
Behavioural tests for the assessment of social motivation



Note. Representation of the behavioural tests used to measure the three components of social motivation. See the text for full descriptions of the procedure of each test.

Figure 2.2

Methods for the assessment of sociability and social cognition



Note. Representation of the methods used to measure the sociability and social cognition. See the text for full descriptions of the procedure of each test and the questionnaire.

2.3. MATERIALS

The most relevant materials used in the behavioural test battery are described below. The food rewards used were pieces of sausage, unless the subject had some dietary restriction, or the caregiver thought that other type of food could be more motivating for their dog.

Unsolvable task. An apparatus consisting of a plastic container with its lid fixed to a wooden table (59.5 x 30 x 1 cm) (Figure 2.3). Throughout the study the container had to be replaced, so two types were used (container 1: 14 x 11 x 5.5 cm; container 2: 11 x 11 x 4.5 cm). The container had several holes in its bottom part so the subject could smell the food reward.

Figure 2.3

Apparatus used in the unsolvable task test (container 2)



Object choice tasks. Opaque plastic cups of the following dimensions were used: 9.5 cm tall, 7.5 cm diameter in the superior part, 4.5 cm diameter in the bottom (Figure 2.4).

Figure 2.4

Plastic cup used in the object choice tasks



Play test. Two types of toys were used: rope bone (type A) and ball with rope (type B). Since some toys had to be replaced during the study, but the same model could not be found, the same toys were not used for all the subjects (but they were of the same types). In each trial the two toys were always identical. Two models were used of toy type A, and four models of toy type B (Figure 2.5; left to right: toys A1, A2, B3, B2, B4). Toy B1 does not appear in the image but was similar to B2, except that the rope ended in the ball (there was no knot on the other side).

Figure 2.5

Toys used in the play test



Food begging test. A stool of the following dimensions was used: 80.5 cm tall, 32.5 cm diameter (seat), 32/45 cm wide (distance between its legs) (Figure 2.6).

Figure 2.6

Stool used in the food begging test



Conformity test. The transparent lids of some plastic containers, of 12.5 cm diameter, were used as plates (Figure 2.7).

Figure 2.7

Plate used in the conformity test



2.4. PROCEDURE

Before the day of the first session, the experimenter sent out to the caregivers a document with instructions and considerations for the testing days. The caregivers were asked not to feed their dog in the 4 hours before the session, and to give them a walk before the session or try to avoid having the session during times associated with walks. For the first session, they were told that the dog should not see the experimenter before the first test. In the cases in which the caregiver did not follow this indication, the experimenter made sure that contact with the subject was minimum and asked the caregiver to take the dog to a different room until the first test was initiated. The document also requested that distractions were kept to a minimum, avoiding interferences by other individuals as much as possible. On the day of the first session, the experimenter sent the caregivers the link to the personality questionnaire, which they could fill out in the platform Google Forms.

The procedure of the tasks that made up the battery as well as the questionnaire are described below (see also Figure 2.1 and Figure 2.2). The tests are classified according to the construct they were intended to measure. The variables that were recorded for each test along with the test description and the definition of each variable are presented in Table A.5

2.4.1. Social orienting

2.4.1.1. *Eye contact test*

Based on the protocol by Putrino et al. (2014). The procedure consisted of two parts of 1 minute each. In the first one, the experimenter, who had a video camera on her chest, called the subject and, when they were in front of her, she started the timer on her phone and started giving them pieces of food at variable intervals, while she talked to them (dog-directed speech). The experimenter made sure that the subject could see where the food was taken from, which was on a container out of reach of the animal. A maximum of five pieces of food were delivered and at the end of the minute the second part of the test started. In this part, the experimenter called the subject by their name and gave them one final piece of food. Then, she started the timer on her phone and gazed at the subject for 1 minute, standing next to the food container. In the cases in which the subject showed signs of fear with the experimenter standing, the test was carried out with the experimenter crouching down. The recorded variables were the latency to first gaze at the experimenter and the gaze duration.

2.4.1.2. *Unsolvable task*

Based on protocols by Passalacqua et al. (2011) and Scandurra et al. (2015). Before starting the test, the experimenter fixed the apparatus (see description in Materials chapter) to the floor with adhesive tape. The experimenter and the caregiver stood on opposite sides of the apparatus, at approximately 50 cm from it, facing it. The caregiver held the subject, while the experimenter baited the apparatus. The test consisted of three initial solvable trials, in which the experimenter showed the subject how she placed three pieces of food on the lid of the container that was fixed to the board, and then covered them with the plastic container placed upside down. Then, the experimenter took her position and asked the caregiver to release the dog, starting the timer on her phone. The caregiver was only allowed to give a command in those cases in which the subject needed it as a signal indicating that they were allowed to eat the food. To obtain the food the subject simply had to move the plastic container. The trial ended when the subject

obtained the food or after 1 minute. If the subject obtained the food in at least two out of three trials, a final trial was carried out, which was unsolvable. In this trial the procedure was the same, with the exception that, after covering the food with the plastic container, the experimenter closed it with the lid that was fixed to the board. The trial ended after 1 minute or if the subject managed to obtain the food. The caregiver was instructed to stay in the designated spot and ignore the subject (avoiding eye contact) during the trial, like the experimenter. The registered behaviours were gazing at the apparatus and at humans (caregiver or experimenter) (latency and duration), interacting with the apparatus and with humans (latency and duration) and alternating gaze between apparatus and humans (frequency and latency).

2.4.2. Social reward

2.4.2.1. *Separation episodes*

Adapted from Cook et al. (2016). The episode started when the subject's caregiver left home, while the experimenter stayed inside with the subject on leash. The caregiver was instructed to return and enter the house after 1 minute. The caregiver and the experimenter were synchronized and measured the time with a chronometer (generally with their phones). Approximately 45 seconds after the caregiver left, the experimenter showed a piece of food to the subject (their favourite treat), placed it on their food bowl and left the bowl on the floor. The food bowl was placed on a spot opposite to the entrance of the house, so the experimenter and the subject on leash were between the entrance door and the food bowl, which were equidistant. When the minute was over, the caregiver entered the house, closed the door and stood in a spot by the door previously indicated by the experimenter. Then, the experimenter released the subject so they could choose. The caregiver was instructed to stand still next to the door without talking to the subject. If the subject approached the caregiver (at arm's reach), they could greet them as they would usually do. If the subject approached the food bowl, they could eat the treat. We registered the first choice. Given that after an initial group of subjects was tested it was observed that there would probably be low variability regarding the first choice (i.e., most subjects chose the food), we decided to examine as well if they approached the caregiver after

choosing the food. To this end, the experimenter waited between 5-30 seconds or until the subject left the test zone or stayed in front of the experimenter ignoring the caregiver. Four separation episodes were carried out, which were interspersed with the rest of the tests (see Table 2.1).

2.4.2.2. *Play test*

Based on protocols by Gruber (2014) and E. MacLean & Hare (2013). The caregiver was sitting on a chair, holding the subject in front of them. At a distance of 2 meters there was a plastic tape 1.2 meters long, fixed to the floor with adhesive tape. At the start of each trial, the experimenter, who had a video camera on her chest, stood behind the middle point of the tape and showed two identical toys (rope bone or ball with rope) to the subject, holding one on each hand and shaking them, not looking at the subject. Next, she crouched and placed both toys on the floor simultaneously, one at each end of the tape. Then, she went behind one of the toys and kneeled. After kneeling down, the experimenter gave the indication to the caregiver to release the subject and started the chronometer. The trial lasted 1 minute, during which the subject was free to choose whether to play or not and with which toy, and the caregiver was instructed to remain sitting and ignore the subject. The experimenter remained looking at the toy in front of her and only if the subject approached her (at arm's reach) invited the subject to play, moving the toy on the floor and talking (dog-directed speech). If the subject grabbed the toy, the experimenter played with them grabbing the other end of the toy. If the subject was playing with the experimenter when the minute ended, the experimenter suddenly let go of the toy, interrupting the game. The interruption period lasted 1 minute, during which the experimenter didn't move, only looked at the subject and sometimes took the video camera from her chest to hold it and follow the subjects' movements.

Four trials were run; in the first two trials the toys used were rope bones, and in the last two they were balls with a rope. The side of the toy behind which the experimenter kneeled was counterbalanced between trials and pair of toys. The order was the same for all the subjects (except one, due to an experimenter's error). Between subjects, the toys were washed with water and textile detergent not harmful for dogs (in a few cases, usually when several dogs were tested in the same household, the toys presented had not been

washed). The recorded variables were the first toy approached, the first toy touched, the duration of proximity to the experimenter and the duration of interaction with each toy. In addition, in the interruption period we coded the frequency of re-engagement behaviours, the duration of gazing at the experimenter, the frequency of gaze alternation between toy and experimenter, the duration of individual play, the latency to stop playing and the duration of proximity to the experimenter.

2.4.3. Social maintaining

2.4.3.1. *Conformity test*

Based on protocols by S. Marshall-Pescini et al. (2011); Sarah Marshall-Pescini et al. (2012) and Prato-Previde et al. (2008). The caregiver was sitting on a chair, holding the subject in front of them. At a distance of 2 meters there was a plastic tape 1.2 meters long, fixed to the floor with adhesive tape. At the beginning of the test there was a pre-test, in which the subject could choose between two plates with different amounts of food (small amount: one piece; large amount: six pieces). At the start of each trial, the experimenter knelt behind the middle point of the tape and placed both plates on the floor simultaneously, one on each end of the tape. While she placed the plates the experimenter looked at the subject to check if they looked at both plates. Then, the experimenter stood up and, if the subject had not looked at both plates during the placement, she waited until they would do so (with a maximum of approximately 30 seconds). Next, the experimenter turned their back on the subject, took a step forward (away from the tape) and gave the indication for the caregiver to release the subject. The caregiver was instructed to notify the experimenter when the subject started to eat food from one of the plates, so she could take away the other plate. The pre-test consisted of a maximum of six trials and the goal was to check whether the subject showed a preference for the large amount. Therefore, initially only those subjects that chose the large quantity in at least four trials moved on to the next phase. This criterion was applied to the first 75 subjects, and 47 (63%) did not reach it. Given that a great number of subjects did not reach this criterion, we decided to eliminate it. Thus, from this point on, the pre-test

consisted of six trials for all the remaining subjects ($n = 24$), and all subjects moved on to the following phase independently of their score on the pre-test.

In the following phase, the procedure was similar with the exception that the experimenter showed interest for the plate with the small quantity. After placing both plates on the floor and waiting for the subject to look at both (with a maximum of approximately 30 seconds), the experimenter kneeled behind the plate with the small amount. Then, she grabbed the piece of food, brought it close to her face, looked at it, then at the subject and finally back at the food and said in Spanish with a happy tone “How tasty! How tasty this is!”. Next, she left the piece of food on the plate and stood up to go to the same position as in the pre-test, that is, with her back turned to the subject at the middle point between both plates, away from the tape. As in the previous phase, the experimenter gave the indication for the caregiver to release the subject, and once the subject started eating from one of the plates, the other was taken away. This phase consisted of six trials. In both phases the position of the plates was counterbalanced, with the restriction that the same position could not be repeated in more than two consecutive trials. The order of the trials was the same for all subjects. The main variable was the plate chosen.

2.4.3.2. *Synchronization test*

Adapted from Duranton, Bedossa, et al. (2017). The caregiver and the subject started the test in the same room. The caregiver was sitting on a chair, and once the subject was passive (could be standing, sitting or lying, but not moving), the experimenter indicated the start of the test. Then, the caregiver took a route previously explained by the experimenter, in which the caregiver did the following: 1) stand up and walk during 15 seconds towards another room, 2) at the end of the 15 seconds, sit on a chair located on that second room and remain sitting for 15 seconds, 3) stand up and walk during 15 seconds back to the first room, 4) at the end of the 15 seconds, sit on the chair where the test had started and remain sitting for 15 seconds. At the end of these 15 seconds the test was over. Thus, the test consisted of four phases of 15 seconds each, that is, it lasted for 1 minute. Although the time was measured by the caregivers using a chronometer, the duration of the phases turned out to be different for each caregiver, what was considered

during the analyses. During the test the caregiver was instructed to ignore the subject, who was free to move wherever they wanted. The experimenter recorded the test with a camera, focusing on the subject, but trying to interfere as less as possible. The main variables were the duration of synchronized activity (movement/stationary), the latency to switch to the same activity of the caregiver and the latency to follow the caregiver in phase 1. In addition, each subject received a score between 0 and 2 based on their following behaviour.

2.4.4. Sociability

2.4.4.1. Behavioural test

Based on the protocol by Jakovcevic et al. (2012). The experimenter was sitting on a chair, placed against a wall or piece of furniture, and situated inside a plastic semi-circumference with a radius of 1 meter fixed to the floor with adhesive tape. After the indication of the experimenter, the caregiver entered the room with the subject on leash or grabbing them by the collar, closed the door, and sat on another chair located at approximately 2 meters from the experimenter's chair. Then, the experimenter asked the caregiver to release the subject and initiated the timer on her phone. The test consisted of two phases of 1 minute each. In the first phase, the experimenter remained passive, looking at her phone, stroking the dog briefly each time they established physical contact, but avoiding eye contact. If the subject remained in physical contact for 10 seconds, the experimenter stroked it again. At the end of the minute, the experimenter got up from the chair and took it away, putting it outside of the semi-circumference in a nearby spot where it interfered as little as possible. Then, she knelt inside the semi-circumference, in the spot where the chair was previously located, and initiated the timer in her phone. In the second phase, the experimenter called the dog by their name and interacted with them if they approached (entered the semi-circumference). The interaction consisted of talking and stroking the dog. One of the subjects showed possible aggression signals (tense body, growling), so the experimenter stopped stroking and only talked to him. If the subject moved away (outside of the semi-circumference), the experimenter called again. Each time the subject moved away, the experimenter could call the subject up to three times,

in 10 seconds intervals. The caregiver was instructed to remain sitting and to ignore the dog during the whole test, and they could use their phone and fill out the personality questionnaire if they wished to do so. The experimenter was always a woman unfamiliar to the subject, generally the PhD candidate herself. In the cases in which the subject already knew the PhD candidate, a helper, who had received an explanation of the protocol, played the role of experimenter. The registered variables were the latency to approach the experimenter and to establish physical contact with her, and the duration of proximity to and of physical contact with the experimenter in each phase.

2.4.4.2. Dog Personality Questionnaire (DPQ)

The questionnaire used in this study was a modified version of the Dog Personality Questionnaire by Amanda Claire Jones (2008). This questionnaire was chosen because it was elaborated specifically with the intention of measuring personality (as opposed to the C-BARQ, which was developed in the context of the assessment of behavioural problems, although admittedly can also be used to measure personality traits; Hsu & Serpell, 2003), is not based solely on adjectives (as opposed to the MCPQ-R; J. Ley et al., 2008; J. M. Ley et al., 2009), and has demonstrated adequate psychometric properties for the evaluation of dog personality (Amanda Claire Jones, 2008). Particularly, we started working with the long form of the DPQ, which consists of 75 items that measure five factors: 1) Fearfulness, 2) Aggression towards People, 3) Activity/Excitability, 4) Responsiveness to Training and 5) Aggression towards Animals. The Aggression towards People factor is correlated with both the Fearfulness and the Aggression towards Animals factors. Each factor is subdivided into several facets. The Fearfulness factor comprises four facets: Fear of People, Non-social Fear, Fear of Dogs and Fear of Handling. The Aggression towards People factor has two facets: General Aggression and Situational Aggression. The Activity/Excitability factor is subdivided into four facets: Excitability, Playfulness, Active Engagement and Companionability. The factor Responsiveness to Training also has two facets: Trainability and Controllability. Finally, the Aggression towards Animals factor contains three facets: Aggression towards Dogs, Prey Drive and Dominance over Other Dogs.

Although in the DPQ the Companionability facet is related to sociability and the Aggression towards People factor also makes reference to friendliness towards people, given that this questionnaire didn't have a sociability factor or facet per se but still had items that could be related to the construct, we decided to work with a modified version that included only a selection of items. Since we were only interested in dog-human interactions, we excluded all items related to interactions with other animals (which involved discarding all items of the facet "Fear of Dogs" from factor 1, as well as all items from factor 5) and modified item 46 ("Dog is interested in playing tug-o-war with people or dogs") to exclude interaction with dogs. This left us with 55 items, which were translated to Spanish by two native Spanish speakers fluent in English (the PhD candidate and another person unrelated to the study). These translations were contrasted and a pool of items in Spanish was generated, which was then back translated by two additional persons (one a native English speaker and bilingual, the other a native Spanish speaker with formal education on translation). Adjustments were made where deemed necessary to obtain the final pool of 55 items in Spanish.

Since we were only interested in measuring sociability, three experts in dog behaviour were asked to rate the degree of association each item had with the human-oriented social motivation/sociability of the dog. No distinction was made between social motivation and sociability since the items did not allow discrimination and we were interested in measuring sociability in its broadest sense. For this purpose, they had to score on a scale from 1 to 5 how closely related each item was to the dog's disposition towards and interest for social contact with humans (with 1 indicating no relationship and 5 the maximum degree of relationship), regardless of the direction of the association (an item could suggest a low social motivation but still receive a score of 5). 32 of the initial 55 items received an average score equal or higher than 3, which was the cut-off value we established for inclusion in the final questionnaire. The agreement between raters was relatively low (intraclass correlation coefficient (ICC) = .63; average measures, absolute-agreement, two-way mixed effects model). Apart from the experts' ratings, we considered the importance of each item at the theoretical level when deciding which items to include in the questionnaire. After a revision of the 32 items, we discarded one item that we believed didn't have a relevant association with sociability/social motivation ("Dog tends to be calm"). Moreover, we recovered three items which we thought might be related to sociability/social motivation, despite being below the cut-off value. One of these items

(“Dog gets bored in play quickly”) was modified to specify that it referred to interactions with humans. Thus, the final questionnaire had 34 items consisting of adjectives and behavioural descriptions, which belonged to the factors Fearfulness, Aggression towards People, Activity/Excitability and Responsiveness to Training of the original DPQ (Table 2.2). The dog caregivers rated in a 7-point Likert scale (from “completely disagree” to “completely agree”) the degree to which each sentence described their dog.

Table 2.2

Dog personality questionnaire items

Item (number in original DPQ)	Factor	Facet
1) Está relajado cuando saluda a la gente* (1)	Fearfulness	Fear of people
2) Se comporta de manera agresiva si se le molesta o se le mueve cuando está descansando (2)	Aggression towards people	Situational aggression
3) Le encanta recibir elogios (7)	Activity / excitability	Companionability
4) Cuando está suelto, viene inmediatamente cuando lo llamo (11)	Responsiveness to training	Controllability
5) Es tímido (12)	Fearfulness	Fear of people
6) Se comporta de manera agresiva hacia personas desconocidas (13)	Aggression towards people	General aggression
7) Se aburre enseguida al jugar con personas* (16)	Activity / excitability	Playfulness
8) Se comporta de manera agresiva cuando se restringe su movimiento o se le manipula (ej. ser acicalado) (17)	Aggression towards people	Situational aggression
9) Es seguro de sí mismo* (19)	Fearfulness	Non-social fear
10) Se comporta de manera agresiva cuando una persona (ej. visitante, repartidor) se acerca a la casa o al patio (23)	Aggression towards people	General aggression
11) Es ruidoso (27)	Activity / excitability	Excitability
12) Se comporta de forma miedosa durante las visitas al veterinario (28)	Fearfulness	Fear of handling
13) Se comporta de forma miedosa cuando está cerca de multitudes de gente (30)	Fearfulness	Fear of people

Table 2.2 (continued)

Item (number in original DPQ)	Factor	Facet
14) Se disgusta fácilmente cuando se le corrige, regaña o castiga (32)	Fearfulness	Fear of handling
15) Es amigable con personas desconocidas* (33)	Aggression towards people	General aggression
16) Busca la compañía de las personas (35)	Activity / excitability	Companionability
17) Está atento a las acciones y palabras de su dueño (37)	Responsiveness to training	Trainability
18) Es curioso (40)	Activity / excitability	Active engagement
19) Se comporta de manera agresiva en respuesta a amenazas percibidas de personas (ej. ser acorralado, que le intenten agarrar del collar) (43)	Aggression towards people	Situational aggression
20) Es esquivo* (44)	Activity / excitability	Companionability
21) Está interesado en jugar al tira y afloja con la gente (46)	Activity / excitability	Playfulness
22) Se comporta de forma miedosa hacia personas desconocidas (47)	Fearfulness	Fear of people
23) Se comporta de manera agresiva durante las visitas al veterinario (51)	Aggression towards people	Situational aggression
24) Se comporta de forma miedosa hacia los niños (54)	Fearfulness	Fear of people
25) Es muy excitable cuando llegan visitas (55)	Activity / excitability	Excitability
26) Deja comida u objetos cuando se le dice (56)	Responsiveness to training	Controllability
27) Busca y trae objetos (ej. pelotas, juguetes, palos) (59)	Activity / excitability	Playfulness
28) Exhibe comportamientos de miedo cuando se restringe su movimiento (61)	Fearfulness	Fear of handling
29) Es cariñoso (63)	Activity / excitability	Companionability
30) Ignora las órdenes* (64)	Responsiveness to training	Trainability
31) Sigue a la gente (67)	Activity / excitability	Companionability

Table 2.2 (continued)

Item (number in original DPQ)	Factor	Facet
32) Muestra agresividad cuando está nervioso o asustado (68)	Aggression towards people	General aggression
33) Se comporta de manera agresiva hacia los niños (73)	Aggression towards people	General aggression
34) Se comporta de forma miedosa cuando es acicalado (74)	Fearfulness	Fear of handling

Note. Items marked with an asterisk were reversed.

2.4.5. Social cognition

2.4.5.1. Object choice task – pointing

Based on the protocols by D’Aniello et al. (2017) and Duranton, Range, et al. (2017). The caregiver was sitting on a chair, holding the subject in front of them. At a distance of 2 meters there was a plastic tape 1.2 meters long, fixed to the floor with adhesive tape. At the start of the test there was a warm-up phase, with two trials. In these trials, the experimenter, kneeling behind the middle point of the tape, showed a piece of food to the subject while she called their name. Then, she placed it on the middle point of the tape and covered it with an opaque plastic cup upside down (a different cup was used in each trial). Next, the experimenter indicated the caregiver to release the subject, who could explore the cup and obtain the food. In this phase the experimenter could help the subject obtain the food, and the caregiver could encourage the subject if necessary. If the subject showed signs of fear, additional steps were incorporated to habituate the subject to the cup. The goal of this phase was that the subject learned that there was food under the cup and, in case of being afraid of the cup, that they were able to touch it. Subjects could receive additional warm-up trials after starting the experimental phase if deemed necessary by the experimenter.

After the warm-up phase, the experimental tests were carried out. At the beginning of each trial, the experimenter asked the caregiver to leave the room with the subject or that they went to an area in which they could not see the experimenter. In some cases, the

caregiver was allowed to remain sitting with the subject, generally to avoid stressing the subject due to having to move repeatedly. In those cases, the caregiver was asked to cover the eyes of the subject. Once she was sure that the subject could not see her, the experimenter placed a piece of food on one of the ends of the plastic tape, covering it with an opaque cup, and placed an identical cup on the other end. Then, she knelt behind the middle point of the tape and indicated the caregiver that they could return to the room and sit on the chair, placing the subject in front of them and trying that they were centred (equidistant to both cups). The caregiver was instructed not to look at the cups and not to talk to the animal. Next, the experimenter called the subject by their name, said “look”, and pointed at the baited cup with the index finger of the ipsilateral arm. If the subject didn’t look at the experimenter after saying their name, the experimenter called again until they established eye contact before saying “look” and performing the pointing gesture. The sequence (“Name, look” and pointing) was repeated three times in each trial, and in the last repetition the experimenter kept her extended finger at approximately 10 cm from the cup (i.e., dynamic sustained proximal pointing), lowered her head and looked to the floor. Then, the experimenter indicated the caregiver to release the subject, who had approximately 10 seconds (mentally counted by the experimenter) to choose a cup, touching it with their muzzle or paw. If the subject chose the correct cup, the experimenter lifted it and allowed them to eat the reward. If they chose the incorrect cup, the experimenter lifted it to show that there was no food under it, and then showed the food under the other cup. If they didn’t choose any cup, the trial was repeated, and they had a maximum of three attempts to complete the trial. Six trials were carried out in which the side of the baited cup was counterbalanced, and the same side could not be repeated in more than two consecutive trials. The order of the trials was the same for all subjects.

2.4.5.2. Object choice task – gazing

The procedure was the same as in the previous test, with the difference that, instead of pointing with the finger, the experimenter turned her head and gazed at the baited cup. In this case, after repeating the gesture three times in each trial, the experimenter remained with her head turned and gazing at the cup (i.e., sustained gaze). Again, the subject had approximately 10 seconds (mentally counted by the experimenter) to choose a cup, touching it with their muzzle or paw. Six trials were carried out in which

the side of the baited cup was counterbalanced, and the same side could not be repeated in more than two consecutive trials. The order of the trials was the same for all subjects.

2.4.5.3. Call test

Inspired by Gácsi et al. (2004) (see also Hare et al., 1998). The caregiver stayed in a room, while the experimenter took the subject to a different room, so the caregiver was out of sight of the subject. After the experimenter's indication, the caregiver called the subject to the room (in the way they would usually do). If she was holding the animal, the experimenter released them in that moment. The caregiver was instructed to call only once, and in case the subject did not come (i.e., enter the room where the caregiver was) after 10 seconds, the experimenter gave the indication to call them again. The trial ended 15 seconds after the subject entered the room where the caregiver was. The caregivers were asked to ignore the animal during the trial. If after three calls the subject did not come to the room, the trial was aborted. Six trials were carried out, which were interspersed with the rest of the tests of the first session (i.e., after each test, a trial of the call test was carried out). In half of the trials the caregiver was facing the door (or area) through which the subject would enter the room ("facing" condition), and in the other half they had their back turned to it ("back" condition). The same condition could not be repeated in more than two consecutive trials.

2.4.5.4. Food begging test

Inspired by Gácsi et al. (2004). The experimenter placed a stool with a food container in front of her and called the subject. At the beginning of the test, the experimenter took one piece of food from the container and gave it to the subject. With this, the experimenter got the subject to see that the container, which was out of reach, had food in it, and got the animal to stand at the other side of the stool. Thus, the experimenter and the subject were facing each other, with the stool between them. After delivering three pieces of food, the experimenter acted according to the condition of the trial. In the trials of the "back" condition, the experimenter turned 180°, so that she ended

with her back turned to the stool with the food container and to the subject. In the trials of the “facing” condition, the experimenter took the stool, placed it behind her and kept her position. Therefore, the subject was still in front of her, but the stool with the food container was behind her. Each trial lasted 30 seconds, after which the experimenter turned 180° again (“back” condition) or placed the stool in front of her (“facing” condition). That is, at the end of the trial the experimenter or the stool returned to the starting position. Before the next trial, the experimenter gave one piece of food to the subject to place them again at the starting position. During this test the caregiver could stay in the same room but was instructed to ignore the subject if they approached. Six trials were carried out (three trials per condition), with the conditions counterbalanced, with the restriction that the same condition could not be repeated in more than two consecutive trials. The order of the trials was the same for all subjects.

2.5. DATA ANALYSIS

2.5.1. Data coding

In each test different variables were registered during the experiment or coded from video. In Table A.5 all variables that were coded for each test along with their definition are presented. Videos were coded in Solomon Coder (beta 19.08.02, © András Péter) with a time resolution of 0.2 seconds.

2.5.2. Interobserver reliability

All tests were recorded on video and coded by the main researcher, and a randomly selected 20% of videos were coded by two persons not involved in the study to calculate interobserver reliability. Each observer coded a 20% of videos for some particular tests (observer A: eye contact test, unsolvable task, synchronization test, food begging test; observer B: separation episodes, play test, play test – interruption period, sociability test, call test). The variables of interest of the object choice tasks and conformity test, as well

as some variables of other tests, were considered to have been registered unequivocally, so calculating the interobserver reliability was not deemed necessary.

For continuous variables the intraclass correlation coefficient (ICC) estimates and their 95% confidence intervals were calculated using the *icc* function from *irr* package in RStudio (Gamer et al., 2019), based on single-rating, absolute-agreement, two-way random effects model. For those variables that had a low ICC value ($< .7$), the cases in which there was a high degree of disagreement between the two observers were revised. Given that the two coders who were independent to the study had not been trained and had only received a basic explanation of the behaviours to be coded, for these variables with low reliability, clarifications were made where necessary and they were asked to revise their coding of either the whole sample (the randomly selected 20%) or a subsample that included both subjects that had scores with high agreement and subjects that had scores with low agreement between observers. This revision and clarification were also done for variables that, even having an acceptable ICC value ($> .7$), presented subjects with scores that were remarkably different between observers.

For categorical variables, Cohen's kappa was calculated using the *kappa2* function from *irr* package in R, with values $> .6$ considered acceptable ("substantial" in (Landis & Koch, 1977)). ICC and kappa values of the relevant variables can be found in Table A.6. As can be seen, some variables showed poor interobserver reliability. The low ICC value for the latency to gaze at humans in the unsolvable task was likely due to differences in the procedure followed when coding the behaviours (continuous versus frame-by-frame or a mix of both) and the time resolution of the coding program. Gazing behaviour was only coded when the subject was stationary, but there were instances in which the perception of whether the subject was stationary or moving changed depending on whether the video was coded continuously or frame-by-frame. This issue also affected the variables frequency of and latency to gaze alternation to a degree. The variable first toy touched had a low kappa value and was then replaced by the variable first toy interacted with (see below), which showed acceptable interobserver reliability.

2.5.3. Data pre-processing

Many of the variables that were initially coded were discarded due to a variety of reasons in the data pre-processing phase and were not used in subsequent analyses. Furthermore, in some cases the decision was made to code the variable differently, create a new variable, or to keep only subjects that fulfil certain criteria. These decisions are explained below, and the retained variables can be found in Table 2.3. For descriptive statistics see Tables A.7 and A.8.

Unsolvable task. The test was recoded, considering the test started not when the subject was released, but when the subject first interacted with the apparatus. This meant that each subject had a different test duration and that *latency to interact with apparatus* was dropped. The test duration for each subject was used to calculate relative durations and latencies. For all variables, only subjects that had a test duration ≥ 40 seconds were considered. *Latency to gaze apparatus* and *duration of other behaviours* were considered irrelevant for the main objectives of the present study. *Latency to interact with humans* was eliminated due to low variability (interaction with humans was not frequent, so the majority of subjects had maximum latency). The *duration of gaze* and *duration of interaction* variables were summed to create the variables *duration of attention towards apparatus* and *duration of attention towards humans*. The variable *proportion of attention towards humans* was obtained dividing the *duration of attention towards humans* by the sum of the *duration of attention towards humans* and *towards the apparatus*.

Separation episodes. Only subjects that had data for the four trials were considered. The *first choice* variable was used to obtain the number of trials they chose the caregiver first. Given that there was low variability (most subjects approached the food first), this variable was discarded. Since the first choice was the only variable we planned to use initially, at the beginning of data collection the experimenter finished the test immediately after the first choice. However, it was soon clear that this variable would probably not be useful, and that the subjects' behaviour after their first choice might be more informative. For this reason, we also coded whether the subject approached the option not chosen first (the subjects that were tested first don't have this data since the experimenter didn't wait after their first choice). We were especially interested in whether the subjects that chose the food first in the four trials approached and greeted the caregiver afterwards, so we

only kept these individuals. We registered the *frequency of approaching the caregiver after choosing food* for these subjects.

Play test. For all variables, only subjects that approached one of the two toys in the four trials were considered. Moreover, for each variable, to avoid having individuals with different number of trials, we kept only those subjects that had data for all trials. Since the *first toy touched* had a low interobserver reliability (on some occasions it was hard to determine whether the subject made physical contact with the toy or only sniffed closely), it was replaced with *first toy interacted with*, which included sniffing, following the toy's movement with head, and physical contact such as rubbing, nosing, licking, pawing, chewing. This variable had an acceptable kappa value. The *frequency they approached the social toy first* and the *frequency they interacted with the social toy first* were calculated. The *duration of interaction* with the toys was relative to the time the subject was "visible" (i.e., time during which it could be determined whether the subject was playing with a toy and with which). The *duration of proximity to E* was averaged across the four trials. Only subjects that were "visible" ≥ 40 seconds in the four trials were considered for the variables *duration of interaction with social/individual toy*. For each trial, a *proportion of social play* was calculated by dividing the *duration of interaction with social toy* by the sum of the *duration of interaction with social toy* and the *duration of interaction with individual toy*. The *proportion of social play* was then averaged across the four trials. The interruption period variables were not included in the main analyses of this study.

Conformity test. Only subjects that completed the test and looked at both plates in all trials of both the pre-test and test were considered. Since the criterion to advance to the test phase was eliminated at a certain point during data collection (see above), some of the subjects that completed the test didn't reach this criterion (i.e., not all subjects chose the large amount in 4 trials in the pre-test). The *proportion of trials the large amount was chosen* in the pre-test and in the test was calculated for each subject. The number of trials was always 6 for the test phase but varied for the pre-test phase for subjects which were still applied the criterion (they had a maximum of 6 trials to reach criterion but as soon as they reached it the pre-test phase stopped). A *change-in-bias* was calculated by subtracting the proportion of the test from the proportion of the pre-test (see also Kis et al., 2022; Turcsán et al., 2018), and thus reflected the influence of the experimenter's behaviour during the test in the subjects' choices (i.e., larger values reflect stronger

conformity or social susceptibility). Nevertheless, the data of this test was affected by an experimenter's error, which meant that in most of the trials the plates were not equidistant to the subject. In some cases, it was not possible to determine from the video which of the plates was closer. We performed a binomial logistic regression analysis to determine the effect of the condition, distance, and side of the plate on the subjects' choices. In this analysis, the dependent variable was whether they chose the plate with the large amount (binary variable), the independent variables were the condition (pre-test or test), the distance of the plate with the large amount (close, far or equidistant, as two dummy variables with equidistant as reference level) and the side of the plate with the large amount (right or left), and the subject was also included as a random effect. First, we tested whether the baseline mixed-effects model (i.e., including random effects) was better than the baseline GLM model (i.e., only fixed effects). The results suggested that including the random effects didn't improve the model, so we worked only with the fixed effects. We performed a stepwise comparison, starting by comparing the null model with the model that had condition as a predictor. The model that was significantly better was then tested against a model in which an additional predictor was added. In summary, the model that included condition as a predictor was significantly better than the null model, and the addition of the other predictors (i.e., distance, side) didn't improve the model. When testing the model with only distance as a predictor against the null model, there was no significant improvement. Therefore, it seems that, overall, it was the condition (i.e., pre-test or test) that was driving subjects' choices.

Synchronization test. Due to the configuration of the test, the visibility of the caregiver was a factor that had to be taken into consideration when interpreting the variables. The *latency to switch to the same activity* in each phase was coded as missing if the caregiver wasn't visible when changing the activity (i.e., at the start of the phase), or if the subject was already doing the activity to which the caregiver switched (e.g., if the dog was already moving when the caregiver started moving). This resulted in an extremely low sample size for these variables, since on most occasions the caregiver was not visible to the subject at the start of the phase. Therefore, we decided to keep only the *latency to move in phase 1*, when the subject and caregiver were necessarily in the same room and therefore the caregiver was visible when starting to move. For ease of interpretation, this variable was transformed into a binary variable, with a value of 1 indicating that the subject moved during phase 1. The variables *latency to follow* and

score were not considered in the main analyses of this study, as they were not synchronization measures. The *relative synchronization* was calculated as the sum of the *duration of synchronized movement* and *synchronized stationary* divided by the total time the caregiver was visible. Only subjects for which the caregiver was visible ≥ 40 seconds were considered.

Sociability test. *Latency to proximity* was discarded due to low variability and a strongly skewed distribution.

Object choice task – pointing. The data from this test was discarded due to low variability (ceiling effect; 81% of the subjects succeeded in the six trials).

Object choice task – gazing. Only subjects that completed the six trials were considered. The *number of successful trials* was calculated.

Call test. Whether the subject *came when called* and the *number of calls* needed were included initially because we thought they might provide interesting information even if they were not considered social cognition measures; however, they were discarded due to low variability (most subjects came when called and only needed one call). Similarly, whether the *subject entered the room*, *stayed in the room*, and *remained in close proximity* to the caregiver didn't provide useful information (i.e., there was practically no difference between conditions in these variables). Therefore, we used only the variables of *gaze occurrence* and *gaze duration*. First, we considered keeping only those subjects that had data for the six trials, but the sample size diminished considerably. Thus, we decided to work only with the data from the first trial the subject came in each condition. Furthermore, we kept only subjects that were visible during at least 10 seconds in those trials. *Gaze occurrence* was selected as the measure of social cognition and since we were interested in the difference in behaviour in the two conditions, we created a score. Subjects that gazed at the caregiver's face in both conditions received a score of 2, subjects that gazed in the back but not the facing condition received a 1.5, subjects that gazed in the facing but not the back condition received a 1, and subjects that didn't gaze in any condition received a 0.

Food begging test. Similarly to the previous test, the sample size diminished considerably when we considered only subjects with data for the six trials. Therefore, we worked only with the data from the first trial of each condition. The *occurrence of vocalizations* was very low, so it was discarded. We created a score with the *success* and

Table 2.3*Retained variables from the behavioural tests*

Test	Variable	Variable description
Eye contact	Latency to first gaze	Time elapsed from the start of the test until S establishes eye contact with E
	Duration of gaze	Time during which S establishes eye contact with E
Unsolvable task	Relative latency to gaze at human	Time elapsed from the start of the trial until, from a stationary position, S gazes a human (E or C) relative to the trial duration for each S
	Proportion of attention towards humans	Duration of attention towards a human (gazing/interacting with E or C) divided by the sum of the duration of attention towards a human and the duration of attention towards the apparatus
	Frequency of gaze alternation	Number of times S alternates gaze (gaze at human's face followed by gaze at apparatus or viceversa, within a 2-second range)
	Relative latency to gaze alternation	Time elapsed from the start of the trial until S alternates gaze (gaze at human's face followed by gaze at apparatus or viceversa, within a 2-second range) relative to the trial duration for each S
Separation episodes	Frequency of approaching C after F	Number of trials they approached C after choosing food
Play	Frequency of approaching social toy first	Number of trials S approached the social toy first
	Frequency of interacting with social toy first	Number of trials S interacted with the social toy first

Table 2.3 (continued)

Test	Variable	Variable description
Play	Average duration of proximity to E	Average time during which S is in proximity to E across the four trials
	Average proportion of social play	Duration of interaction with the social toy divided by the sum of the durations of interaction with both toys (social and individual), averaged across the four trials
Conformity	Proportion of choosing large quantity (pre-test / test)	Number of trials the S chose the plate with the large quantity of food relative to the total number of trials for each S (in the pre-test and test)
	Change-in-bias	Proportion of trials the S chose the large quantity in the pre-test minus the proportion of trials the S chose the large quantity in the test
Synchronization	Movement in phase 1	Whether the S moved in phase 1 after C started moving
	Relative synchronization	Duration of synchronized activity (synchronized movement plus synchronized stationary) relative to the time C was visible
Sociability	Latency to physical contact with E	Time elapsed from the start of the test (C releases S) until S establishes physical contact with E
	Duration of proximity to E (phase 1 / 2)	Time during which S is in proximity to E (S has at least one body part, except the tail, inside or over the semi-circumference)
	Duration of physical contact with E (phase 1 / 2)	Time during which S is in physical contact with E
Object choice – gazing	Success	Number of successful trials

Table 2.3 (continued)

Test	Variable	Variable description
Call	Score	0 = S doesn't gaze at C in any condition 1 = S gazes at C in the facing but not in the back condition 1.5 = S gazes at C in the back but not in the facing condition 2 = S gazes at C in both conditions
Food begging	Success score	0 = S wasn't successful in any condition 1 = S was successful in the facing but not in the back condition 1.5 = S was successful in the back but not in the facing condition 2 = S was successful in both conditions
	Gaze score	0 = S doesn't gaze at E in any condition 1 = S gazes at E in the facing but not in the back condition 1.5 = S gazes at E in the back but not in the facing condition 2 = S gazes at E in both conditions

Note. E = experimenter, S = subject, C = caregiver

gaze variables, which followed the same distribution as in the call test.

2.5.4. Statistical analyses

The statistical analyses were conducted in IBM SPSS Statistics version 27, jamovi version 2.3.18 (The jamovi project, 2022) and RStudio version 2023.3.1.446 (Posit team, 2023). All tests were two-tailed and statistical significance was tested at the .05 level unless otherwise indicated.

2.5.4.1. Correlational analyses

In order to verify the first hypothesis, which posited that the three categories of social motivation, i.e., social orienting, reward, and maintaining, proposed by Chevallier et al. (2012) in humans, can be supported empirically in dogs, and that they indeed represent behavioural manifestations of the same construct, we planned to conduct a confirmatory factor analysis. As a first step in the structural analysis of the social motivation tests, we analysed the correlation patterns. However, examination of the correlation matrix of the social motivation tests revealed scarce significant correlations, which were of small size (see Results chapter). This, summed to the low sample size when only complete cases were considered, meant that a factor analysis of the social motivation tests was not feasible. Thus, we worked only with the results of the correlational analyses.

To verify the second and third hypotheses, which proposed a positive association between social motivation, sociability and social cognition, we conducted correlational analyses between the variables of the behavioural tests. We also explored the correlations between the Dog Personality Questionnaire factors and the behavioural variables.

The Kendall correlation coefficient was used for ordinal variables, as well as for continuous variables, since they didn't follow a normal distribution and some of them were truncated. Point and rank biserial correlations were calculated for the association between binary and continuous, and binary and ordinal variables, respectively. Only significant correlations will be reported in the Results chapter (for all correlations see Tables A.9-A.17). Scatterplots, bar plots and boxplots of the variables that are

significantly correlated can be found in Figures A.1 and A.2. When describing the magnitude of the correlations, the corresponding cut-off values for Kendall's tau are used: very weak: $|\tau| < .15$, weak: $.15 \leq |\tau| \leq .25$, moderate: $.25 < |\tau| \leq .40$, strong: $.40 < |\tau| \leq .60$, very strong: $|\tau| > .60$.

2.5.4.2. Factor analysis of the Dog Personality Questionnaire

A factor analysis of the questionnaire was carried out to verify that the subset of items we selected and translated maintained the factor structure from the original questionnaire. Our questionnaire was composed of items that belonged to the "Fearfulness", "Aggression to people", "Activity/Excitability" and "Responsiveness to training" factors in the original DPQ. Thus, a confirmatory factor analysis (CFA) was performed, in which each item was assigned to the factor it belonged to in the original DPQ. The analysis was conducted in RStudio using the *lavaan* package (Rosseel, 2012). The validity of the model was evaluated based on (1) acceptable levels of goodness-of-fit, and (2) evidence of construct validity.

As model fit measures we used the comparative fit index (CFI), Tucker Lewis index (TLI) and goodness-of-fit index (GFI), as well as the root mean square error of approximation (RMSEA). For the CFI, TLI and GFI values $\geq .95$ were considered indicative of good fit, while values $\geq .90$ indicated an acceptable fit. For the RMSEA a value $\leq .05$ (90% CI $\leq .08$) was considered indicative of a good fit, while a value $\leq .08$ (90% CI $\leq .10$) indicated an acceptable fit.

We considered that the model was validated if there was evidence of convergent and discriminant validity. Convergent validity was evaluated through the statistical significance and the size of the factorial loadings, as well as the average variance extracted (AVE). Discriminant validity was evaluated comparing the AVEs of each pair of factors with the square of the correlation between them. The reliability of the factors was evaluated through Cronbach's alpha. Items with standardized loadings above $|\cdot 40|$ ($p < .05$) and latent factors with AVE above $.40$ were taken as evidence of convergent validity. Evidence of discriminant validity was obtained when the estimations of the AVE for two factors were higher than the square of the correlation between those factors. To

achieve a good internal consistency, Cronbach's alpha values of .70 or higher were necessary.

2.5.4.3. Cluster and profile analyses

To check whether we could find different classes or profiles of individuals in our sample based on their behaviour in sociability and social motivation tests, we performed a cluster analysis (CA). We followed the same procedure for all cluster analyses, which were run in RStudio. First, we checked for outliers computing Mahalanobis distances, which were compared against a chi-square distribution with degrees of freedom equal to the number of dependent variables and an alpha level of .005 (Hair Jr. et al., 2019). Then, we assessed clustering tendency through the Hopkins statistic, which measures the probability that the dataset is generated by a uniform data distribution, using the *get_clust_tendency* function from *factoextra* package (A. Kassambara & Mundt, 2020). We established a threshold of $H > .50$ to decide that the data was significantly clusterable (Alboukadel Kassambara, 2018b).

We used both hierarchical (agglomerative) and non-hierarchical (k-means) clustering methods. As a measure of dissimilarity we used the Euclidean distance. First, to choose between different linkage methods (Ward, complete and average) of the agglomerative hierarchical clustering, we compared internal validation measures (connectivity, Dunn and silhouette indices) using the *cIValid* function of the same name package in R (Brock et al., 2008). Solutions that minimized connectivity and maximized Dunn and silhouette indices were favoured. In addition, we examined the correlation between the cophenetic distance and the original distance for the three linkage methods, and considered acceptable values above .75 (Alboukadel Kassambara, 2018a). With this information we tried to select one linkage method for the hierarchical clustering.

In order to determine the optimal number of clusters for both hierarchical and k-means clustering, we used the *NbClust* function. We chose the number of clusters for each clustering method based on the majority rule (i.e., the number of clusters that were indicated as optimal by the majority of indices).

Then, we compared the hierarchical and k-means solutions using internal validation measures (connectivity, Dunn and silhouette indices). We also examined the silhouette plots and checked whether there were any observations with a negative silhouette index, which implies that they are probably assigned to the wrong cluster.

For the solutions retained after the previous steps, we examined whether the obtained clusters significantly differed in the variables that were used to generate the clusters (i.e., the clustering variables), which would indicate they were contributing to the distinctiveness of the clusters. Lastly, as a final validation step we assessed whether the clusters differed in variables that were not used as clustering variables but that could be theoretically related to them (Hair Jr. et al., 2019). In the case of continuous variables, for comparing two groups we used Students' t-test when the homogeneity of variances assumption (verified by Levene's test) and the normality assumption (verified by Shapiro-Wilk test) were met. If only the former assumption was violated, we used Welch's t-test, while if the normality assumption was violated, we used Mann-Whitney U test. As indicators of the effect size, we used Cohen's d for Student's and Welch's t tests, and rank-biserial correlations for Mann-Whitney U test. For comparing more than two groups we used ANOVA when the homogeneity of variances assumption (verified by Levene's test) and the normality assumption (verified by Shapiro-Wilk test) were met. If only the former assumption was violated, we used Welch's ANOVA, while if the normality assumption was violated, we used Kruskal-Wallis test. As indicators of the effect size, we used η^2 for ANOVA, and ϵ^2 for Kruskal-Wallis. In the case of categorical or ordinal variables we used a chi-square test for independence unless a cell showed an expected frequency lower than 5, in which case we used Fisher's exact test.

We decided to compare the solutions of the traditional CA with those provided by latent profile analysis. While traditional CA is based on distance measures and relies on heuristic procedures, resulting in a certain degree of subjectivity, latent profile analysis (LPA) is a model-based clustering method, which allows the use of existing objective parameters for model selection (Bauer, 2022; Stahl & Sallis, 2012). Thus, if through LPA we arrived at the same or very similar solution(s) to the one(s) obtained through traditional CA, this would give us confidence that the decisions made in the latter were appropriate.

We followed the same procedure for all profile analyses, which were run in RStudio (see Wardenaar, 2021). First, we omitted the same outliers that were removed in

CA. Then, we fit models of types EEI, EEE, VVI and VVV with 1 to 9 profiles using the function *Mclust* of the *mclust* package (Scrucca et al., 2016), which estimates models by expectation-maximization (EM) algorithm initialized by hierarchical model-based agglomerative clustering and suggests the optimal model variant based on the Bayesian Information Criterion (BIC). The model types differ in terms of how the profile-specific (co)variance matrices of the indicator variables are constrained or allowed to vary within and between profiles. We also examined the Integrated Complete Likelihood (ICL) for these model types and number of profiles. In this approach, the BIC and the ICL should be maximized.

Next, for the optimal model we checked the size and means of the profiles, the probabilities of each subject of belonging to each of the profiles, the uncertainty of allocation, as well as the average latent profile posterior probability. Contrary to traditional CA, the profile allocation in LPA is probabilistic, i.e., each individual is assigned a probability for each estimated profile, based on their pattern of scores in the indicator variables. The average latent posterior probabilities are presented in a matrix with diagonal values representing the average probability of individuals belonging to one profile being assigned to that profile given their scores on the indicator variables (Weller et al., 2020). Thus, higher diagonal values are desirable, with values lower than .80 considered unacceptable.

To verify the solution, we additionally estimated the models with a different function, *estimate_profiles* from *tidyLPA* package (Rosenberg et al., 2019), which allows comparison of several indices (including LogLik, AIC, AWE, BIC, CAIC, CLC, KIC, SABIC and ICL) for different model types and number of profiles, and indicates the model that optimizes each index. We checked which model optimized the majority of indices and whether it coincided with the optimal model proposed by the *mclust* function. The selected model(s) was then compared to the one(s) selected in traditional CA in terms of the profile interpretation and the composition of the profiles.

2.5.4.4. Additional analyses

We checked whether there were any associations between the demographic variables, i.e., sex and age (in years), and the variables from the behavioural tests, as well

as the questionnaire-derived factors. We didn't consider breed since comparing mixed and purebred dogs didn't seem sensible, as purebred dogs were a heterogeneous group. We could have divided the purebred dogs into cooperative and non-cooperative breeds (e.g., see Gácsi, McGreevy, et al., 2009), but the uncertainty associated with the classification process dissuaded us from doing so.

Regarding sex, in the case of continuous variables we compared males and females using Students' t-test when the homogeneity of variances assumption (verified by Levene's test) and the normality assumption (verified by Shapiro-Wilk test) were met. If only the former assumption was violated, we used Welch's t-test, while if the normality assumption was violated, we used Mann-Whitney U test. We also considered the reproductive status and compared the four groups (i.e., intact males, neutered males, intact females and spayed females) using ANOVA when the homogeneity of variances assumption (verified by Levene's test) and the normality assumption (verified by Shapiro-Wilk test) were met. If only the former assumption was violated, we used Welch's ANOVA, while if the normality assumption was violated, we used Kruskal-Wallis test. In the case of categorical or ordinal variables we used a chi-square test for independence unless a cell showed an expected frequency lower than 5, in which case we used Fisher's exact test.

Regarding age, as before, the Kendall correlation coefficient was used for ordinal variables, as well as for continuous variables, since they didn't follow a normal distribution and some of them were truncated. Point biserial correlations were calculated for the association with binary variables.

CHAPTER 3 – RESULTS

3.1. HYPOTHESIS 1: BEHAVIOURAL MANIFESTATIONS OF SOCIAL MOTIVATION

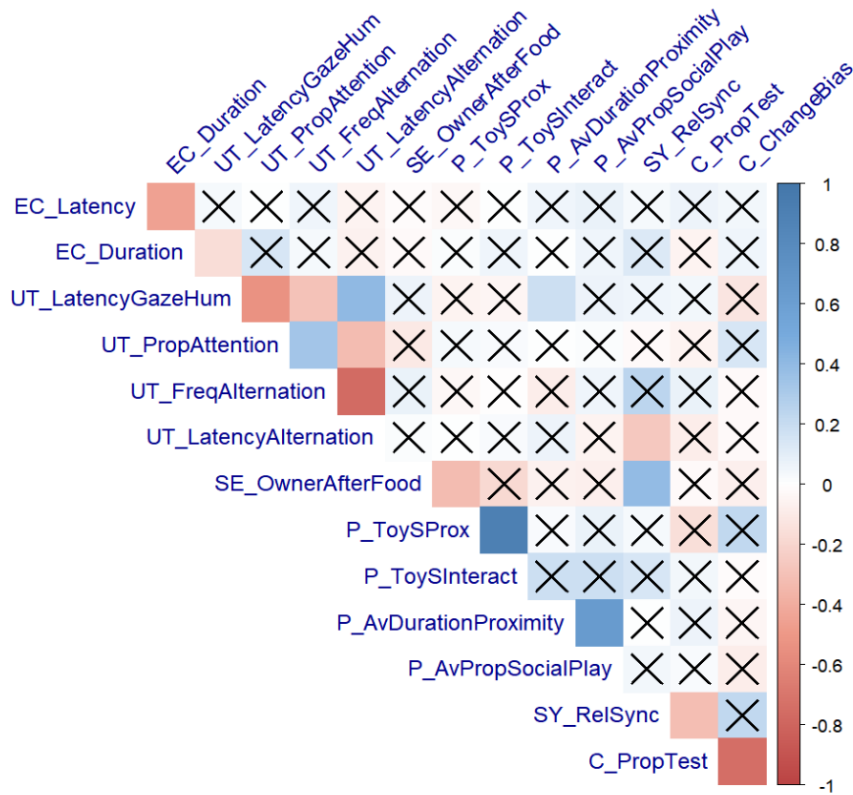
As a first step in the structural analysis of the social motivation tests, we analysed the correlation patterns. Given that all tests were intended to measure the same construct (i.e., social motivation), we expected that variables between tests were correlated. Moreover, to obtain empirical evidence of the three categories of social motivation, we would require variables of tests within the same social motivation category to have a stronger correlation between them than with variables of tests from a different category (e.g., variables of tests from the social orienting category would be more strongly correlated between them than with variables of tests from the social reward category). In other words, correlations within categories should be higher than correlations between categories.

As can be seen in the correlation matrix (Figure 3.1), the majority of significant correlations and those with the highest values were between variables within the same test. Few correlations between tests reached significance ($p < .05$), and they were weak-moderate (highest correlation estimate: .386) (Table 3.1). The strongest correlations were not always between variables from the same category. Among the three strongest correlations, two were within category and one (the highest) was not. Some correlations went in the opposite direction to what was expected.

Given the scarcity of significant correlations, the small size of the few significant correlations and the low sample size when only complete cases were considered, a factor analysis of the social motivation tests was not feasible.

Figure 3.1

Correlation matrix of the social motivation tests



Note. Non-significant correlations ($p > .05$) are crossed. EC = eye contact test; UT = unsolvable task; P = play test; SE = separation episodes; SY = synchronization; C = conformity

Table 3.1

Significant correlations among social motivation variables

Variables		N	Estimate	p-value
Duration of eye contact (EC – social orienting)	Rel. latency to gaze human (UT – social orienting)	72	-.169	.039
Rel. latency to gaze human (UT – social orienting)	Av. duration of proximity (P – social reward)	61	.183	.04
Rel. latency to gaze alternation (UT – social orienting)	Relative synchronization (SY – social maintaining)	34	-.269	.023

Table 3.1 (continued)

Variables		N	Estimate	p-value
Freq. approach C after F (SE – social reward)	Freq. approach social toy first (P – social reward)	41	- .326	.014
Freq. approach C after F (SE – social reward)	Relative synchronization (SY – social maintaining)	25	.386	.012
Relative synchronization (SY – social maintaining)	Prop. of trials chose large quantity in test (C – social maintaining)	23	- .323	.043

Note. The test and social motivation category of each variable are indicated in parenthesis. In bold are correlations within category, in italics correlations in unexpected direction. C = caregiver; F = food; EC = eye contact test; UT = unsolvable task; P = play test; SE = separation episodes; SY = synchronization; C = conformity

3.2. HYPOTHESIS 2: ASSOCIATIONS BETWEEN SOCIAL MOTIVATION AND SOCIABILITY

The second hypothesis predicted a positive association between the behavioural manifestations of social motivation and sociability. Similarly to what was observed in the analysis of social motivation tests, there were few significant correlations between variables from the sociability test and variables from social motivation tests, and these were very weak-weak (highest correlation: .238) (Table 3.2). Variables from the sociability test only correlated with variables from the eye contact and play tests. Correlations went in the expected direction.

Table 3.2*Significant correlations between sociability variables and social motivation variables*

Sociability variable	Social motivation variable	N	Estimate	p-value
Latency to physical contact	Duration of eye contact (EC – social orienting)	84	- .149	.048
Duration of proximity phase 2	Freq. interact with social toy first (P – social reward))	56	.214	.044
Duration of physical contact phase 2	Freq. interact with social toy first (P – social reward)	56	.238	.023

Note. The test and social motivation category of each variable are indicated in parenthesis. EC = eye contact test; P = play test

3.3. HYPOTHESIS 3: ASSOCIATION OF SOCIAL COGNITION WITH SOCIABILITY AND SOCIAL MOTIVATION

The third hypothesis predicted a positive association between performance in the socio-cognitive tests and the different behavioural manifestations of social motivation as well as sociability. When examining the associations between variables from the sociability test and social motivation tests with variables from the social cognition tests, again, there was a scarcity of significant correlations (Table 3.3). Only variables from the play test correlated with social cognition variables. The score in the call test was moderately correlated with the average proportion of social play, but in the opposite direction to our expectations. The scores in the food begging test showed weak positive correlations with the number of trials the subject approached the social toy first in the play test.

Table 3.3

Significant correlations between social cognition variables and variables from the sociability and social motivation tests

Social cognition variable	2nd variable	N	Estimate	p-value
Call test				
Score	Proportion of social play (P – social reward)	49	-.262	.023
Food begging test				
Success score	Freq. approach social toy first (P – social reward)	67	.243	.022
Gaze score	Freq. approach social toy first (P – social reward)	67	.223	.042

Note. The test and social motivation category of each variable are indicated in parenthesis. In italics are correlations in unexpected direction. P = play test

3.4. DOG PERSONALITY QUESTIONNAIRE

First, we performed a CFA with a 4-factor model (Fearfulness, Aggression towards People, Activity/Excitability and Responsiveness to Training factors). The CFI, TLI and GFI were close to reaching the acceptable threshold ($\geq .90$), while the RMSEA indicated an acceptable fit ($\leq .08$). We compared the estimates of the model fit indices we obtained in our modified DPQ with those obtained by Jones (2008) in the original 75-item DPQ and found that they were better in our sample (Table A.18).

Regarding convergent validity, all factors except Responsiveness to Training had at least one item with a standardized loading $< \pm .40$ (Table A.19). No factor reached an AVE of .40, with Aggression towards People and Responsiveness to Training having the highest values (Fearfulness = .33, Aggression towards People = .37, Activity/Excitability

= .07, Responsiveness to Training = .37). Especially Activity/Excitability showed very poor convergent validity based on the items factor loadings, their p-values and the AVE.

The correlations between factors are presented in Table A.20. We found a significant correlation between Fearfulness and Aggression towards People, like in the original questionnaire, but also between Activity/Excitability and both Fearfulness and Aggression towards People. To examine discriminant validity for each factor pair we compared the AVEs of the two factors to the squared correlation between the two. The AVEs must be higher than the squared correlation. There was little evidence of discriminant validity, except for the factor Responsiveness to Training. The author of the original DPQ already noted some discriminant validity issues (Amanda Claire Jones, 2008).

Finally, internal consistency was good for Fearfulness and Aggression towards People, while Activity/Excitability and Responsiveness to Training were slightly below the threshold (Cronbach's alpha; Fearfulness = .80, Aggression towards People = .83, Activity/Excitability = .67, Responsiveness to Training = .69).

Since we were particularly interested in the Companionability facet from the Activity/Excitability factor, which clearly included items closely related to sociability/social motivation, we decided to test a 5-factor model, in which Companionability was not a facet from Activity/Excitability but a separate factor. Table 3.4 presents the comparison of model fit indices of the 5-factor and the 4-factor models. As can be seen, based on the CFI, TLI, GFI and RMSEA the 5-factor model showed a better fit. Convergent validity for the Activity/Excitability factor improved considerably, as evidenced by only one standardized loading below .40 (Table A.21) and an AVE = .32 (compared to .07 in the 4-factor model). The Companionability factor didn't show optimal convergent validity, with three out of five items having a standardized loading below .40, but the AVE was similar to those from the other factors (AVE = .31).

Table 3.4*Comparison of 4-factor and 5-factor model fit indices*

Fit Index	4-factor model fit estimate	5-factor model fit estimate
CFI	.869	.910
TLI	.850	.902
GFI	.839	.857
RMSEA	.064 [90% CI: (.053, .074)]	.052 [90% CI: (.039, .063)]

The correlations between factors of the 5-factor model are presented in Table A.22. The correlation between the factor Activity/Excitability and the factors Fearfulness and Aggression towards People was no longer significant. Instead, the new Companionability factor correlated significantly with these two factors. Thus, it seems that the Companionability facet was driving the correlation between Activity/Excitability and the factors Fearfulness and Aggression towards People in the 4-factor model. No significant correlation was found between the Activity/Excitability and Companionability factors in the 5-factor model. This model showed more evidence of discriminant validity, with the only exception being the separation between Fearfulness and both Aggression towards People and Companionability.

Lastly, in this model Activity/Excitability showed good internal consistency, while the new Companionability factor was below the threshold (Cronbach's alpha; Activity/Excitability = .70, Companionability = .58).

Next, we analysed the correlations between the factor scores of the 5-factor model of the questionnaire (obtained by summing the items' scores; for descriptive statistics see Table A.23) and variables from the sociability test (Figure 3.2 and Table 3.5), social motivation (Table 3.6) and social cognition tests (Table 3.7). The factors Fearfulness, Aggression towards People and Companionability had several significant correlations with sociability behavioural variables, that were weak in magnitude. Fearfulness, Activity/Excitability and Companionability showed weak to moderate correlations with variables from social motivation tests, but the majority went in the opposite direction to what was expected. Activity/Excitability, Companionability and Responsiveness to Training were weakly correlated with social cognition variables.

Figure 3.2

Correlation matrix of the DPQ factors with the sociability test

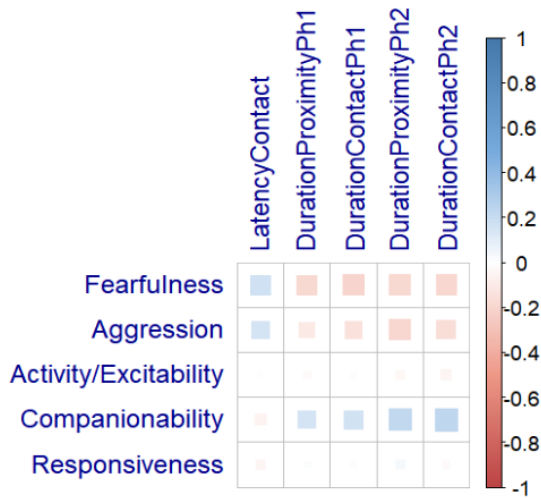


Table 3.5

Significant correlations between DPQ factors and variables from the sociability test

DPQ factor	Sociability variable	Estimate	p-value
Fearfulness	Latency to physical contact	.179	.013
	Duration of proximity phase 1	-.181	.011
	Duration of physical contact phase 1	-.203	.004
	Duration of proximity phase 2	-.188	.009
	Duration of physical contact phase 2	-.195	.006
Aggression towards People	Latency to physical contact	.151	.037
	Duration of proximity phase 2	-.199	.006
	Duration of physical contact phase 2	-.167	.019
Companionability	Duration of proximity phase 1	.151	.040
	Duration of physical contact phase 1	.163	.029
	Duration of proximity phase 2	.224	.002
	Duration of physical contact phase 2	.238	.001

Note. n = 93 for latency to physical contact and phase 1 variables, and n = 98 for phase 2 variables.

Table 3.6*Significant correlations between DPQ factors and variables from social motivation tests*

DPQ factor	Social motivation variable	N	Estimate	p-value
Fearfulness	Av. duration of proximity (P – social reward)	77	-.171	.03
Activity/Excitability	Freq. approach social toy first (P – social reward)	78	-.267	.003
	Av. duration of proximity (P – social reward)	77	.221	.005
	Prop. of trials chose large quantity in test (C – social maintaining)	43	.281	.015
	Change-in-bias (C – social maintaining)	43	-.253	.026
Companionability	Relative synchronization (SY – social maintaining)	51	-.208	.037

Note. The test and social motivation category of each variable are indicated in parenthesis. In italics correlations in unexpected direction. P = play test; SY = synchronization; C = conformity

Table 3.7*Significant correlations between DPQ factors and variables from social cognition tests*

DPQ factor	Social cognition variable	N	Estimate	p-value
Activity/Excitability	Gaze score in food begging test	82	-.206	.02
Companionability	Score in call test	89	.217	.013
Responsiveness to Training	Score in call test	89	.172	.049

Note. In italics correlations in unexpected direction.

3.5. CLUSTER AND LATENT PROFILE ANALYSES

3.5.1. Sociability

3.5.1.1. Cluster analysis

We first performed a CA using only variables from the sociability test. Since multicollinearity can be an issue when performing CA, we only kept one variable from each test phase, which was the duration of proximity. We checked for outliers computing Mahalanobis distance and one case was removed ($n = 92$). A Hopkins statistic value of 0.72 suggested that the data was clusterable.

We considered the use of both hierarchical (agglomerative) and non-hierarchical (k-means) clustering methods. First, we compared internal validation measures (connectivity, Dunn and silhouette indices) to choose between different linkage methods (Ward, complete and average) of the agglomerative hierarchical clustering. The 2-cluster solution with Ward linkage had the best values for the Dunn and silhouette indices. Moreover, we examined the correlation between the cophenetic distance and the original distance for the three linkage methods. Although the three linkage methods had correlation coefficients above 0.75, the highest value was for Ward linkage. Therefore, we decided to work with the Ward algorithm in the following steps.

In order to determine the optimal number of clusters, we used the *NbClust* function. The majority rule suggested a 2-cluster solution for the hierarchical method with Ward linkage and a 3-cluster solution (followed closely by a 2-cluster solution) for k-means (non-hierarchical method). Therefore, we considered a 2-cluster solution with Ward algorithm and k-means, and a 3-cluster solution with k-means in the next steps.

Comparison of internal validation measures (connectivity, Dunn and silhouette indices) showed that the 2-cluster solution with Ward algorithm and with k-means were highly similar. Examination of the silhouette plot revealed that the main difference was that the only observation that had a negative silhouette index in the Ward solution, which implied that it was probably assigned to the wrong cluster, was correctly placed in the other cluster in the k-means solution. Thus, we only considered the k-means solution in

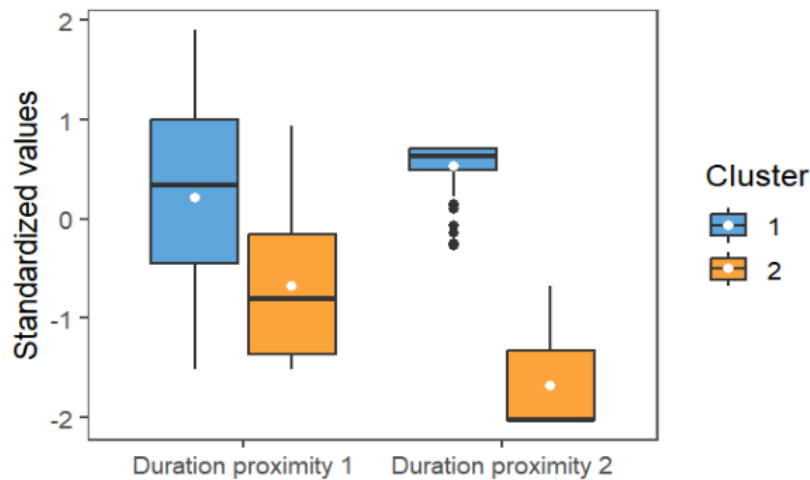
the subsequent steps. The 3-cluster solution with k-means didn't have any observations with a negative silhouette index, suggesting that all observations were placed in the correct cluster.

The cluster sizes for the 2-cluster solution were 70 and 22, and the first cluster had higher mean values in both variables (duration of proximity in phase 1 and in phase 2) than the second one (see Figure 3.3 and Table A.24). A Mann-Whitney test confirmed that the distribution of scores on both variables for the two clusters were not equal (duration of proximity phase 1: $Mdn_1 = 32$, $Mdn_2 = 12.4$, $U = 373$, $p = .035$, rank-biserial correlation = .52; duration of proximity phase 2: $Mdn_1 = 58.2$, $Mdn_2 = 0$, $U = 0$, $p < .001$, rank-biserial correlation = 1). This cluster division was supported by the fact that there was a significant difference between the clusters in the DPQ Fearfulness and Aggression towards People factor scores, with cluster 2 having higher values, as expected (Fearfulness: $M_1 = 29.9$, $M_2 = 40.1$, Student's $t(90) = -3.94$, $p < .001$, Cohen's $d = -0.96$; Aggression: $Mdn_1 = 14$, $Mdn_2 = 19.5$, Mann-Whitney $U = 463$, $p = .005$, rank-biserial correlation = .4). Although cluster 2 had a lower median in Companionability, there were no significant differences between clusters in this factor. Unexpectedly, cluster 2 also had significantly higher scores in the Activity/Excitability factor than cluster 1 ($Mdn_1 = 28$, $Mdn_2 = 33$, Mann-Whitney $U = 475$, $p = .007$, rank-biserial correlation = .38). We explored potential differences between clusters in variables from the social motivation and social cognition tests, but there was no significant difference.

The cluster sizes for the 3-cluster solution were 42, 22 and 28. The first cluster had the highest mean value of proximity duration in phase 1, the second cluster had the lowest mean value of proximity duration in phase 2, and the third cluster was characterized by having the lowest mean value of proximity duration in phase 1 but a very high mean proximity duration in phase 2 (see Figure 3.4 and Table A.25). A Kruskal-Wallis test revealed that the difference between clusters in the two variables was significant, indicating that both were contributing to the distinctiveness of the clusters (duration of proximity phase 1: $\chi^2 = 63.08$, $p < .001$, $\varepsilon^2 = .69$; duration of proximity phase 2: $\chi^2 = 53.02$, $p < .001$, $\varepsilon^2 = .58$). Pairwise comparisons (Dwass-Steel-Critchlow-Fligner -DSCF-) revealed that cluster 1 differed significantly from clusters 2 and 3 in the duration of proximity in phase 1 (clusters 1 and 2: $W = -8.45$, $p < .001$; clusters 1 and 3: $W = -9.97$, $p < .001$), while cluster 2 was significantly different from clusters 1 ($W = -9.39$, $p < .001$) and 3 ($W = -8.58$, $p < .001$) in the duration of proximity in phase 2.

Figure 3.3

Boxplots of the 2-cluster k-means solution



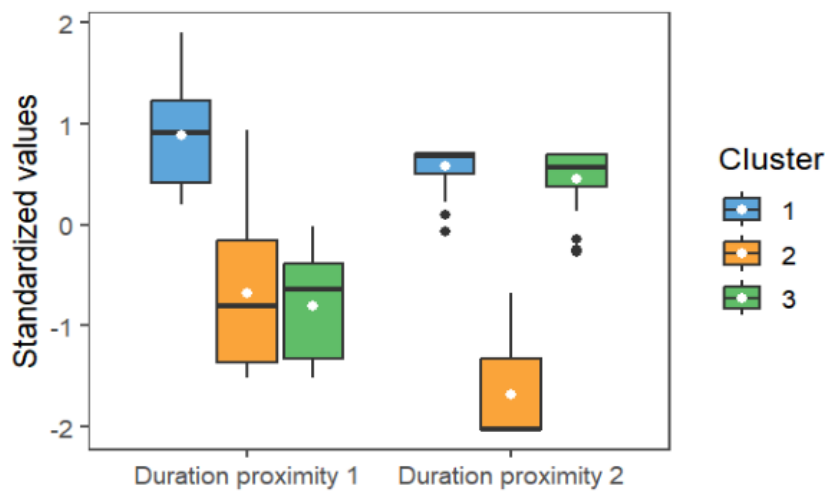
Note. The boxplots show the distribution of the clustering variables for the two clusters obtained through k-means. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles)

Therefore, cluster 1 was composed of individuals that were mainly characterized by having spent a long time close to the experimenter in phase 1, when she was passive. Given that the experimenter was a stranger and didn't provide any indication of whether she was friendly or hostile before the subject approached in phase 1 (she ignored the subject and didn't pet them until they established physical contact with her), subjects in cluster 1 can be seen not only as the most sociable, but also as the boldest or less fearful. In phase 2, when the experimenter was kneeling and called the subject in a friendly manner, individuals from clusters 1 and 3 showed a high proximity duration, while individuals from cluster 2 had the lowest mean value. Thus, although individuals from both clusters 2 and 3 were reluctant to approach during phase 1, only individuals from cluster 3 overcame this reluctance in phase 2. Dogs from cluster 3 might have been uncertain whether to approach the experimenter during phase 1, or they might have simply not been as interested given that the experimenter was mostly ignoring them. Dogs from cluster 2 were the least sociable, maintaining a low mean proximity duration in both

phases, which could suggest that they were less interested or more fearful than dogs from the other clusters. For simplicity, we denominated cluster 1 as High Sociability, cluster 2 as Low Sociability and cluster 3 as Medium Sociability.

Figure 3.4

Boxplots of the 3-cluster k-means solution



Note. The boxplots show the distribution of the clustering variables for the three clusters obtained through k-means. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles). Cluster 1 = High Sociability; cluster 2 = Low Sociability; cluster 3 = Medium Sociability

Interestingly, there was a significant difference between clusters in the DPQ Fearfulness ($F(2, 89) = 8.18, p < .001, \eta^2 = .16$; one-way ANOVA) and Aggression towards People ($\chi^2 = 8.07, p = .018, \varepsilon^2 = .09$; Kruskal-Wallis) factors, which provides validity to the clustering solution. Tukey's post-hoc test revealed that regarding the Fearfulness factor it was the Low Sociability cluster that differed significantly from the other clusters, having the highest mean value ($M_1 = 28.9, M_2 = 40.1, M_3 = 31.4$; comparison clusters 1-2: $t(89) = -4, p < .001$; comparison clusters 2-3: $t(89) = 2.89, p = .013$). This supports the interpretation that fear was playing a role in their behaviour during the sociability test. The Low Sociability cluster also had a higher median score on

Aggression towards People than the other clusters ($Mdn_1 = 13.5$, $Mdn_2 = 19.5$, $Mdn_3 = 15$), but only differed significantly from the High Sociability cluster ($W = 3.85$, $p = .018$; DSCF pairwise comparison). Again, there were no significant differences between clusters in Companionability, but a significant difference emerged with respect to Activity/Excitability ($\chi^2 = 9.37$, $p = .009$, $\varepsilon^2 = .1$; Kruskal-Wallis). Surprisingly, given that this factor contains a Playfulness facet, the Low Sociability cluster had the highest median value ($Mdn_1 = 30.5$, $Mdn_2 = 33$, $Mdn_3 = 26$), although it only differed significantly from the Medium Sociability cluster ($W = -4.24$, $p = .008$; DSCF pairwise comparison). No other significant differences between clusters or associations between clusters and other variables were found, including demographic variables (i.e., sex and age group).

3.5.1.2. Latent profile analysis

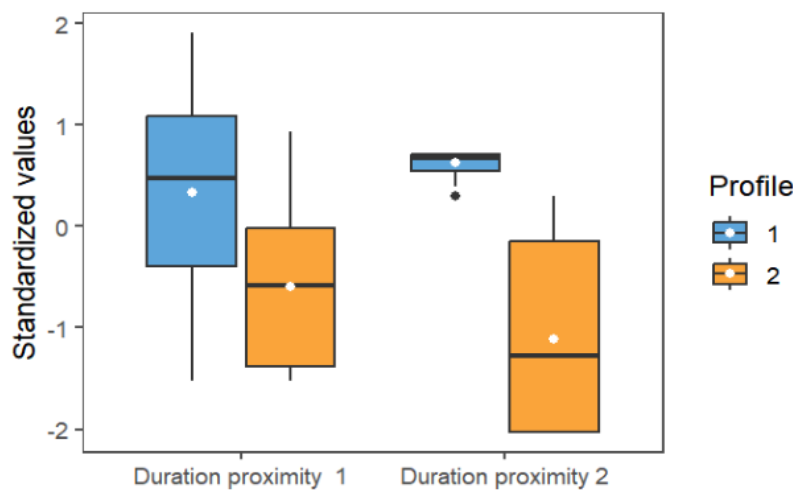
We conducted LPA with the same sociability variables and the same subjects to compare it with the traditional CA solution. The *mclust* function indicated that the top 3 models based on the BIC criterion were (1) VVI with 2 profiles (BIC = -1471.8), (2) VVV with 2 profiles (BIC = -1478.7) and (3) EEI with 5 profiles (BIC = -1513.3). The ICL was also maximized for models VVI and VVV with 2 profiles. It should be noted that several of the models could not be estimated, particularly of the types VVV and VVI. The optimal model (VVI with 2 profiles) showed acceptable average latent posterior probabilities (> 0.9). The *estimate_profiles* function from *tidyLPA* confirmed that, according to the majority rule (i.e., number of optimized indices), VVI with 2 profiles was the optimal model.

The profiles generated had sizes 59 and 33, and the first profile was characterized by having higher mean values in both variables (duration of proximity in phase 1 and in phase 2) than the second profile (duration proximity phase 1: $M_1 = 31.9$, $M_2 = 15.9$; duration proximity phase 2: $M_1 = 58.1$, $M_2 = 20.1$) (see Figure 3.5). Thus, this solution was equivalent in its interpretation to the 2-cluster solution. Yet, the composition of the profiles was different, with 11 individuals from cluster 1 (higher mean values in both variables) belonging to profile 2 (lower mean values in both variables). Interestingly, in the LPA solution there were not only significant differences between profiles in the DPQ

factors Fearfulness ($M_1 = 29.63$, $M_2 = 37.15$, Student's $t(90) = -3.18$, $p = .002$, Cohen's $d = -0.69$) and Aggression towards People ($Mdn_1 = 13$, $Mdn_2 = 17$, Mann-Whitney $U = 608$, $p = .003$, rank-biserial correlation = $.38$), but also in Companionability ($Mdn_1 = 31$, $Mdn_2 = 29$, Mann-Whitney $U = 595$, $p = .002$, rank-biserial correlation = $.39$), all in the expected direction.

Figure 3.5

Boxplots of the VVI 2-profile solution



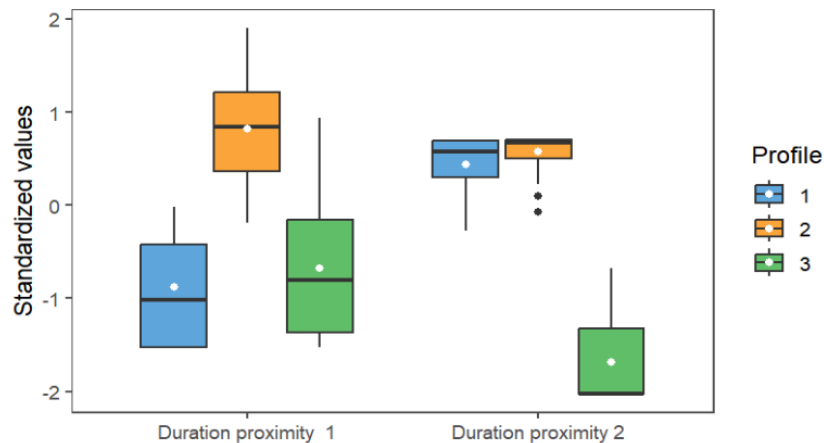
Note. The boxplots show the distribution of the indicator variables for the two profiles of the VVI model. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles).

Finally, we explored the EEI model with 3 profiles, which had a similar BIC to the model with 5 profiles (BIC = -1518.2) (and better than the 4-profile model). This model had acceptable average latent posterior probabilities ($> .8$) and generated profiles of sizes 25, 45 and 22 that were equivalent in their interpretation to the clusters obtained in the traditional CA (see Figure 3.6). When examining the composition of the profiles and the clusters, we found that it was practically identical. Profile 1 was equivalent to the Medium Sociability cluster, profile 2 was equivalent to the High Sociability cluster plus three individuals from Medium Sociability, and profile 3 was equivalent to the Low

Sociability cluster. Expectedly, there were significant differences between profiles in the DPQ factors Fearfulness ($F(2, 89) = 0.83, p < .001, \eta^2 = .16$; one-way ANOVA), Aggression towards People ($\chi^2 = 8.81, p = .012, \varepsilon^2 = .1$; Kruskal-Wallis) and Activity/Excitability ($\chi^2 = 9.71, p = .008, \varepsilon^2 = .11$; Kruskal-Wallis). In this case, however, there was also a significant difference in the change-in-bias variable from the conformity test ($F(2, 37) = 3.65, p = .036, \eta^2 = .17$; one-way ANOVA). Surprisingly, profile 1 (Medium Sociability) had higher mean values than profile 2 (High Sociability) ($M_1 = 0.37, M_2 = 0.11, t(37) = 2.6, p = .035$; Tukey's post-hoc test), which implies that dogs that were sociable (i.e., remained in proximity) only during the active phase of the sociability test were more affected by the experimenter's influence during the conformity test than dogs that were sociable during both phases. Perhaps Medium Sociability dogs were more sensitive to changes in the experimenter's behaviour.

Figure 3.6

Boxplots of the EEI 3-profile solution



Note. The boxplots show the distribution of the indicator variables for the three profiles of the EEI model. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles).

We explored alternative solutions, starting with EEI with 5 profiles, since it was on the top 3 models as indicated by *mclust*. However, this solution showed low average latent posterior probabilities and generated two profiles which were very similar. We checked whether these two profiles would merge in a 4-profile solution, but it wasn't the case. The 4-profile solution also had poor average latent posterior probabilities and was discarded.

3.5.2. Social motivation

In addition, we ran CA and LPA using only variables from social motivation tests. We selected one variable from each test based on their relevance and sample size. Given that only complete cases (i.e., no missing values in any variable) could be used, due to limitations in sample size, variables from the separation episodes, synchronization and conformity tests were not included. Thus, only variables from the eye contact test, unsolvable task and play test were used.

3.5.2.1. Eye contact duration, proportion of attention towards humans and proportion of social play

3.5.2.1.1. Cluster analysis

First, we used as clustering variables the eye contact duration, the proportion of attention towards humans and the proportion of social play. We checked for outliers computing Mahalanobis distance and one case was removed. However, examination of the dendrogram revealed an additional outlier, which was also removed ($n = 44$). A Hopkins statistic value of 0.57 suggested that the data was clusterable ($H > 0.5$).

We considered the use of both hierarchical (agglomerative) and non-hierarchical (k-means) clustering methods, using the same procedure as above. Comparison of internal validation measures (connectivity, Dunn and silhouette indices) did not provide a clear answer but suggested that a 2 or 3-cluster solution with average algorithm might be the best option. Examination of the correlation between the cophenetic distance and the

original distance for the three linkage methods confirmed that the average algorithm was more accurate than Ward and complete algorithms. Only the average linkage method reached a correlation value of 0.75 (0.76). Therefore, we considered only this algorithm in the following steps.

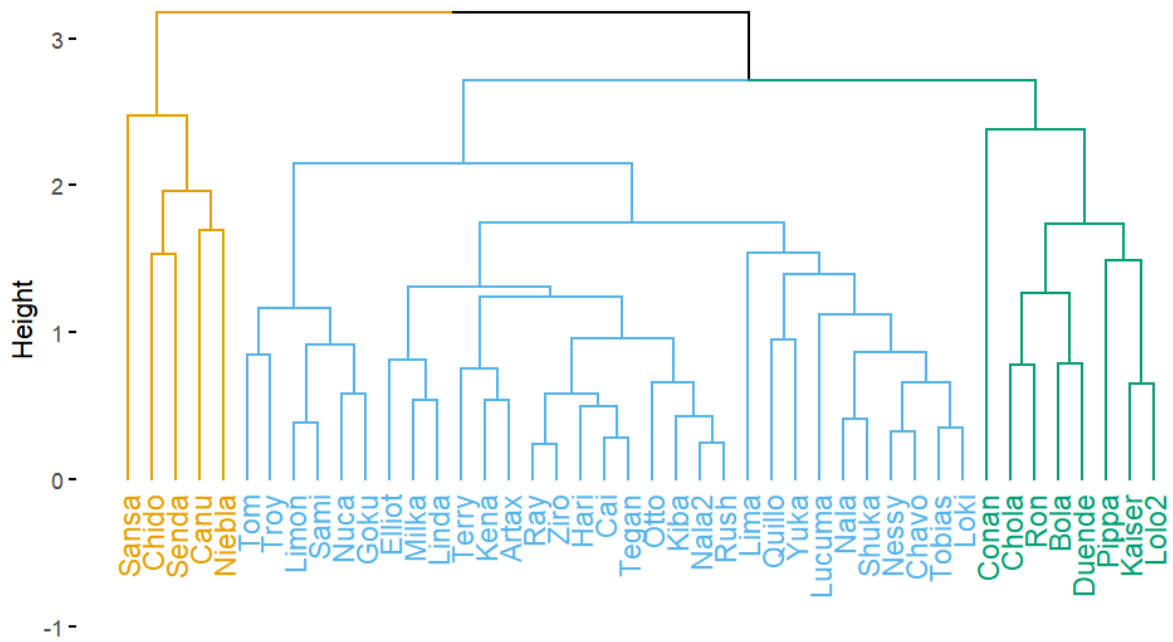
As above, to determine the optimal number of clusters we used the *NbClust* function. The majority rule suggested a 3-cluster solution for the agglomerative hierarchical method with average linkage, and a 4-cluster solution for the k-means method. These are the solutions we considered in the next steps.

Comparison of internal validation measures (connectivity, Dunn and silhouette indices) showed that the 3-cluster solution with the average algorithm was superior to the 4-cluster solution with k-means, so we continued working only with the former. Examination of the silhouette plot revealed only one observation with a negative silhouette index.

The 3-cluster solution using the agglomerative hierarchical method with average linkage generated clusters of sizes 31, 5 and 8. The first cluster was mainly characterized by having the lowest mean duration of eye contact, the second cluster had the highest mean proportion of attention in the unsolvable task, and the third cluster had the lowest mean average proportion of social play (see Figure 3.7, Figure 3.8 and Table A.26). The difference between clusters in the three variables was significant (eye contact duration: $\chi^2 = 13.3, p = .001, \varepsilon^2 = .31$, Kruskal-Wallis; proportion of attention: $\chi^2 = 14.4, p < .001, \varepsilon^2 = .34$, Kruskal-Wallis; proportion of social play: $F(2, 41) = 14.76, p < .001, \varepsilon^2 = .34$, one-way ANOVA), indicating that all were contributing to the distinctiveness of the clusters. Pairwise comparisons revealed that cluster 1 differed significantly from 3 in the duration of eye contact ($W = 4.8, p = .002$; DSCF test), cluster 2 differed significantly from 1 and 3 in the proportion of attention in the unsolvable task (comparison clusters 1-2: $W = 5.02, p = .001$; comparison clusters 2-3: $W = -4.15, p = .009$; DSCF test), and cluster 3 differed significantly from 1 and 2 in the average proportion of social play (comparison clusters 1-3: $t(41) = 5.42, p < .001$; comparison clusters 2-3: $t(41) = 3.27, p = .006$; Tukey's post-hoc test).

Figure 3.7

Dendrogram of the 3-cluster hierarchical solution with average linkage



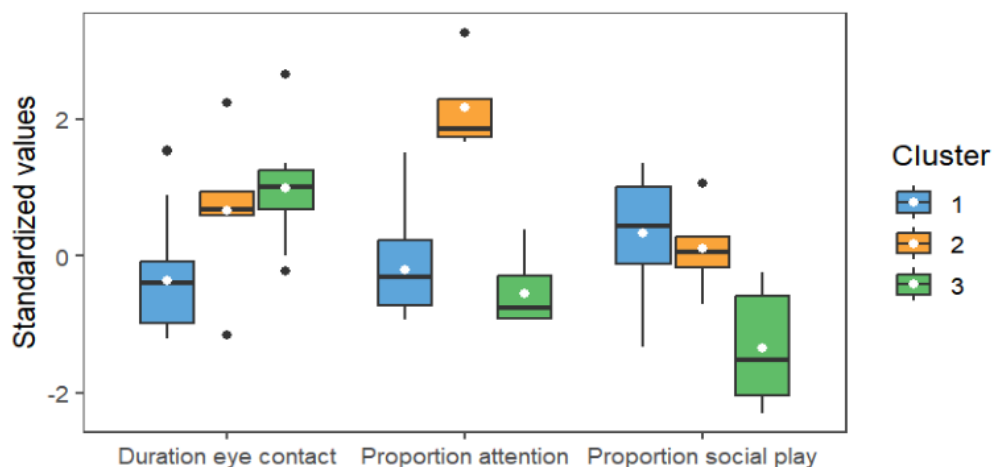
Note. Graphical representation of the hierarchical clustering with average linkage with eye contact duration, proportion of attention towards humans and proportion of social play as clustering variables. The dendrogram shows how the subjects are grouped at each step of the procedure, starting with each individual as a separate cluster at the bottom of the graph and ending with all individuals in a single cluster at the top. The y-axis represents the height of the branch points, which indicates the dissimilarity between the clusters. The colours represent the 3-cluster solution.

Therefore, cluster 1 was composed of individuals that showed low social orienting (lowest mean duration of eye contact and values of proportion of attention in the unsolvable task below average as cluster 3), but high social reward (highest mean average proportion of social play). Thus, cluster 1 could be denominated Low Orienting – High Reward. Individuals from cluster 2 were characterized by having mean values above average in the three tests, thus showing a consistent intermediate-high social motivation, so this cluster could be called Consistent Social Motivation. Finally, individuals from cluster 3 showed high social orienting in one context but not the other, which suggests that they adapted their strategy according to their previous experiences. In the eye contact

test, given that the experimenter had provided food previously, they persisted in gazing at the experimenter. In contrast, in the unsolvable task, where they had been able to get the food on their own in previous trials, they persisted in the individual problem-solving strategy. These individuals also showed the lowest social reward. This cluster could be named Variable Orienting – Low Reward. It might be speculated that the high duration of eye contact in this group was not due to a high social motivation but due to a high interest in getting the food reward. No significant differences between clusters in DPQ scores, nor variables from the other social motivation tests, the sociability and social cognition tests were found. There were also no association with demographic variables (i.e., sex and age group).

Figure 3.8

Boxplots of the 3-cluster solution



Note. The boxplots show the distribution of the clustering variables for the three clusters obtained through hierarchical clustering with average linkage. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles). Cluster 1 = Low Orienting – High Reward; cluster 2 = Consistent Social Motivation; cluster 3 = Variable Orienting – Low Reward

3.5.2.1.2. Latent profile analysis

The *mclust* function indicated that the top 3 models based on the BIC criterion were (1) EEI with 1 profile (BIC = -327.6), (2) VVI with 1 profile (BIC = -327.6) and (3) EEE with 2 profiles (BIC = -331.4). The fact that the LPA suggested a solution with only one profile seems coherent with the somewhat low Hopkins statistic obtained previously ($H = 0.57$), which might imply that this dataset is not clusterable. Still, we continued exploring LPA solutions as we did with traditional CA.

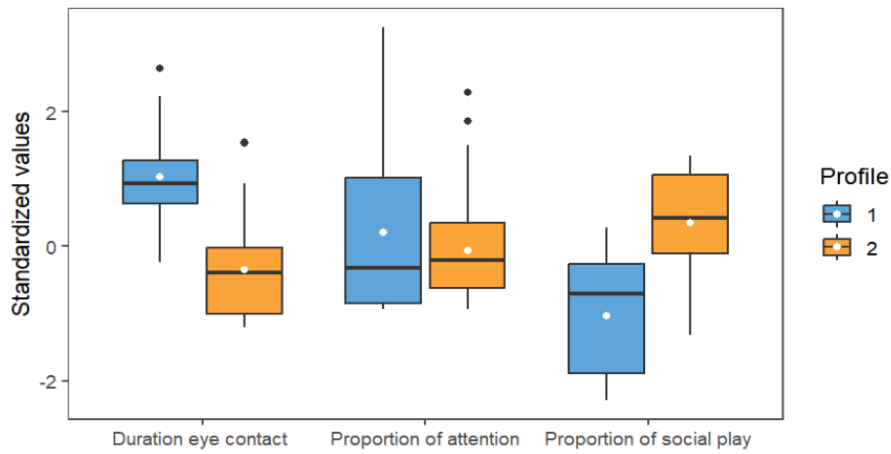
When removing the models with only one profile, the top 3 models were (1) the previously mentioned 2-profile EEE model, (2) EEI with 2 profiles (BIC = -335.6) and (3) VVI with 2 profiles (BIC = -335.7). The ICL was also maximized for model EEE and EEI with 2 profiles. It should be noted that several of the models could not be estimated, more specifically model VVV from 6 to 9 profiles. The optimal model (EEE with 2 profiles) showed acceptable average latent posterior probabilities (> 0.9). The *estimate_profiles* function from *tidyLPA* confirmed that, according to the majority rule (i.e., number of optimized indices), EEE with 2 profiles was one of the most optimal models (tied with 9-profile VVI).

The profiles generated had sizes 11 and 33, and the first profile was characterized by having higher mean duration of eye contact, while the second profile had higher mean values in the average proportion of social play (see Figure 3.9). However, the profiles didn't differ significantly in the proportion of attention towards humans in the unsolvable task. Therefore, we explored alternative solutions, estimating different model types with 3 profiles, since the solution we retained in traditional CA had 3 clusters.

We used the *compare_solutions* function from *tidyLPA* to compare different 3-profile models and according to the majority rule the optimal model type was VVV (although the other type models were close). This model showed acceptable average latent posterior probabilities (> 0.9) and generated profiles of sizes 14, 18 and 12 that were not equivalent in their interpretation to the clusters obtained in the traditional cluster analysis (see Figure 3.10). In addition, the profiles were not significantly different in the variable proportion of attention. Thus, this solution was discarded. Next, we explored the 3-profile EEE solution, which optimized BIC, but it generated a very small profile ($n = 2$). Overall, we didn't find a concordance between the LPA solutions and the traditional CA solution.

Figure 3.9

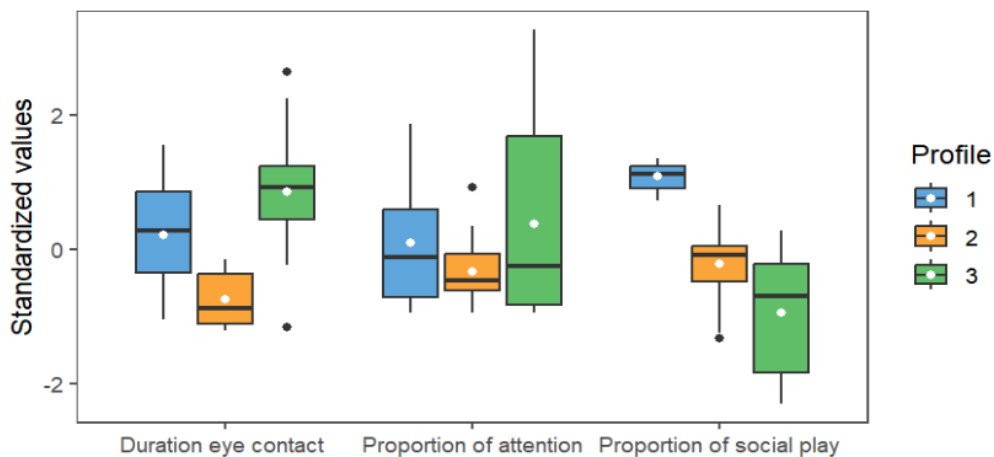
Boxplots of the EEE 2-profile solution



Note. The boxplots show the distribution of the indicator variables for the two profiles of the EEE model. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles).

Figure 3.10

Boxplots of the VVV 3-profile solution



Note. The boxplots show the distribution of the indicator variables for the three profiles of the VVV model. The data of each variable is standardized (subtracting the mean and dividing by the

standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles).

3.5.2.2. *Eye contact duration and proportion of attention towards humans*

3.5.2.2.1. Cluster analysis

Next, we used as clustering variables only the duration variable from the eye contact test and the proportion of attention towards humans from the unsolvable task. Both tests belonged to the social orienting category in our conceptualization. We checked for outliers computing Mahalanobis distance and four cases were removed ($n = 68$). A Hopkins statistic value of 0.73 suggested that the data was clusterable.

Again, we considered the use of both hierarchical (agglomerative) and non-hierarchical (k-means) clustering methods. Comparison of internal validation measures (connectivity, Dunn and silhouette indices) did not provide a clear answer but suggested that the complete and average algorithms were superior to Ward. The higher accuracy of the complete and average algorithms compared to Ward was confirmed when examining the correlation between the cophenetic distance and the original distance for the three linkage methods. Although only the average linkage method reached a correlation value of 0.75, the complete method was extremely close (0.744). Therefore, we decided to explore solutions using both algorithms in the following steps.

As above, to determine the optimal number of clusters we used the *NbClust* function. The majority rule suggested a 3-cluster solution for the three methods (agglomerative hierarchical method with average and complete linkage, and k-means method). In the case of the hierarchical method with average linkage, the 3-cluster solution was followed closely by a 2-cluster solution. Consequently, we considered a 3-cluster solution with average, complete algorithm and k-means, and a 2-cluster solution with average algorithm in the next steps.

Comparison of internal validation measures (connectivity, Dunn and silhouette indices) showed that the 3-cluster solution with the complete algorithm was inferior to

the solution with the average algorithm, so we continued working only with the latter. Although the 3-cluster solution with k-means was only superior in the silhouette index compared to both the 2 and 3-cluster solution with average algorithm, we decided to keep exploring the k-means solution. Examination of the silhouette plot revealed that the 2 and the 3-cluster hierarchical solutions had two observations with a negative silhouette index, while the 3-cluster solution with k-means only had one. Still, we continued exploring the three solutions in the subsequent steps.

The 2-cluster solution using the agglomerative hierarchical method with average linkage generated clusters of sizes 56 and 12. The first cluster had lower mean values than the second one in both variables. However, this difference was only significant for the variable proportion of attention, indicating that the variable duration of eye contact was not contributing to the distinctiveness of the clusters. For this reason, this cluster solution was discarded.

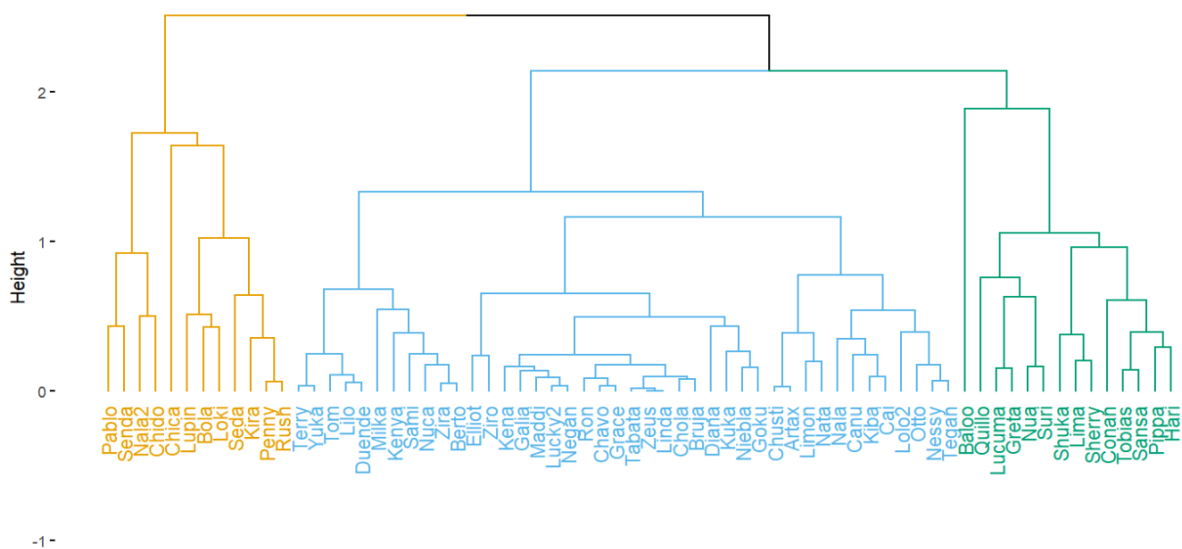
The 3-cluster solution using the agglomerative hierarchical method with average linkage generated clusters of sizes 42, 12 and 14. The first cluster was mainly characterized by having the lowest mean duration of eye contact, the second cluster had the highest mean proportion of attention in the unsolvable task, and the third cluster had the highest mean duration of eye contact (see Figure 3.11, Figure 3.12 and Table A.27). The difference between clusters in the two variables was significant (eye contact duration: $\chi^2 = 36.6, p < .001, \varepsilon^2 = .55$; proportion of attention: $\chi^2 = 29.3, p < .001, \varepsilon^2 = .44$; Kruskal-Wallis), indicating that both were contributing to the distinctiveness of the clusters. DSCF pairwise comparisons revealed that the three clusters differed significantly from each other regarding the duration of eye contact (clusters 1-2: $W = 4.46, p = .005$; clusters 1-3: $W = 7.77, p < .001$; clusters 2-3: $W = 4.77, p = .002$), with cluster 1 having the lowest values, cluster 2 intermediate values, and cluster 3 the highest ones. Regarding the proportion of attention in the unsolvable task, cluster 2 was significantly different from clusters 1 and 3 (clusters 1-2: $W = 7.39, p < .001$; clusters 2-3: $W = -6.12, p < .001$; DSCF). Cluster 2 was composed of individuals that had the highest values in this variable, while both clusters 1 and 3 had lower values.

All in all, individuals from cluster 1 might be those with the lowest social orienting since they established eye contact with the experimenter and directed their attention towards humans for short durations (i.e., Low Orienting cluster). Individuals from cluster 3 seem to have adapted their strategy depending on the test and their immediate previous

experience regarding how they obtained the food reward (i.e., Adaptable Orienting cluster). In the eye contact test, where the experimenter had provided food directly to the subject immediately before, individuals belonging to cluster 3 established eye contact for long durations. On the contrary, in the unsolvable task, where the subjects had previous experience with getting the food from the apparatus by themselves, individuals from cluster 3 had a low proportion of attention towards the humans present. Cluster 2 showed the opposite pattern, having higher orienting in the unsolvable task than in the eye contact test. Dogs from cluster 2 did not stand out in terms of their eye contact duration with the experimenter in the eye contact test but showed a high proportion of attention towards humans in the unsolvable task (i.e., High Attention cluster).

Figure 3.11

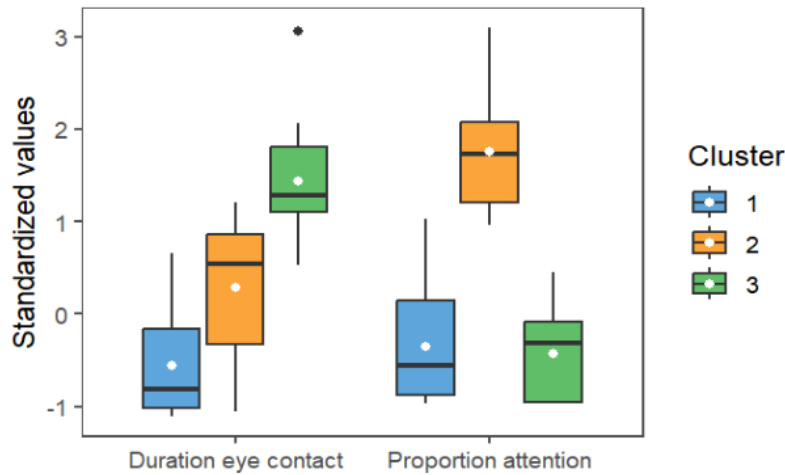
Dendrogram of the 3-cluster hierarchical solution with average linkage



Note. Graphical representation of the hierarchical clustering with average linkage with eye contact duration and proportion of attention towards humans as clustering variables. The dendrogram shows how the subjects are grouped at each step of the procedure, starting with each individual as a separate cluster at the bottom of the graph and ending with all individuals in a single cluster at the top. The y-axis represents the height of the branch points, which indicates the dissimilarity between the clusters. The colours represent the 3-cluster solution.

Figure 3.12

Boxplots of the 3-cluster hierarchical solution



Note. The boxplots show the distribution of the clustering variables for the three clusters obtained through hierarchical clustering with average linkage. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles). Cluster 1 = Low Orienting; cluster 2 = High Attention; cluster 3 = Adaptable Orienting

When exploring differences between the clusters in variables from the other social motivation tests, a significant difference emerged in the relative synchronization ($n_1 = 21$, $n_2 = 5$, $n_3 = 4$; $\chi^2 = 6.75$, $p = .034$, $\varepsilon^2 = .23$, Kruskal-Wallis). DSCF pairwise comparisons specified that only clusters Low Orienting and Adaptable Orienting differed significantly from each other ($W = 3.51$, $p = .035$), with the latter having higher values ($Mdn_1 = .53$, $Mdn_2 = .47$, $Mdn_3 = .71$). Given that subjects from the Low Orienting cluster consistently showed low social orienting (values below average in both the duration of eye contact and the proportion of attention) it seems reasonable that they would also show low social maintaining (i.e., relative synchronization). No other significant differences between clusters in DPQ scores, nor variables from the other social motivation tests, the sociability and social cognition tests were found.

The 3-cluster solution using k-means generated clusters of sizes 17, 38 and 13. Cluster 2 from the k-means solution was equivalent to the cluster Low Orienting, with

the difference that four individuals belonging to this cluster in the hierarchical method were placed in a different cluster in the k-means solution. Cluster 1 was equivalent to cluster Adaptable Orienting from the hierarchical solution, plus three individuals from cluster Low Orienting. Lastly, cluster 3 was analogous to cluster High Attention, with one additional individual from cluster Low Orienting. Therefore, the characteristic attributes of the clusters were the same as in the previous solution (cluster 1 had the highest mean duration of eye contact and cluster 2 the lowest, and cluster 3 had the highest mean proportion of attention in the unsolvable task).

The difference between clusters in the two variables was significant (eye contact duration: $\chi^2 = 39.2$, $p < .001$, $\varepsilon^2 = .59$; proportion of attention: $\chi^2 = 32.7$, $p < .001$, $\varepsilon^2 = .49$; Kruskal-Wallis), indicating that both were contributing to the distinctiveness of the clusters in this solution as well. Pairwise comparisons revealed a similar picture as before, with the three clusters differing significantly from each other regarding the duration of eye contact (in this case cluster 2 had the lowest, cluster 3 had intermediate, and cluster 1 had the highest mean value; $M_1 = 31.1$, $M_2 = 6.15$, $M_3 = 17.1$), while regarding the proportion of attention in the unsolvable task, only one cluster was significantly different from the others (in this case cluster 3, which had the highest values; $M_1 = 0.07$, $M_2 = 0.1$, $M_3 = 0.43$; comparison clusters 1-3: $W = 6.58$, $p < .001$; clusters 2-3: $W = 7.55$, $p < .001$; DSCF). Therefore, interpretation of the profiles of individuals belonging to each cluster would be the same as in the hierarchical solution.

When exploring differences between the clusters in variables from the other social motivation tests, the difference in relative synchronization found in the previous solution was maintained ($n_1 = 4$, $n_2 = 21$, $n_3 = 5$; $\chi^2 = 6.75$, $p = .034$, $\varepsilon^2 = .23$, Kruskal-Wallis). No other significant differences between clusters in DPQ scores, nor variables from the other social motivation tests, the sociability and social cognition tests were found.

3.5.2.2.2. Latent profile analysis

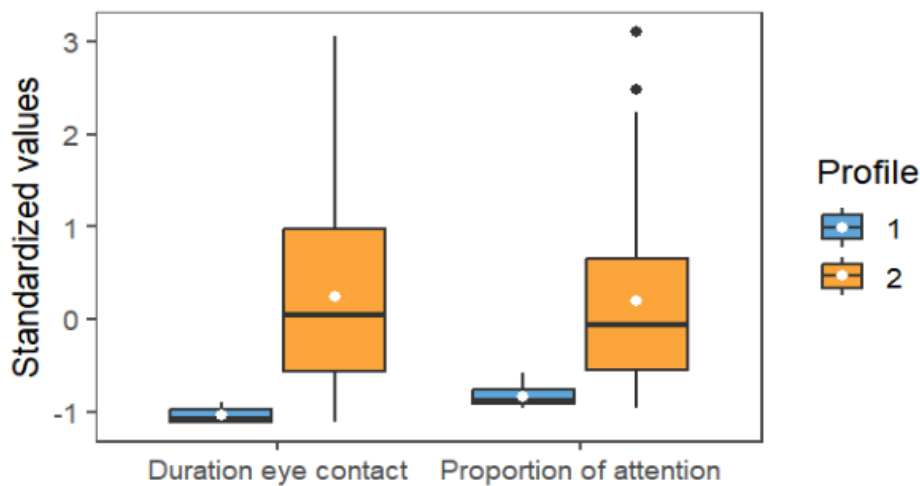
The *mclust* function indicated that the top 3 models based on the BIC criterion were (1) VVI with 2 profiles (BIC = -462.6), (2) VVI with 3 profiles (BIC = -464.4) and (3) VVI with 6 profiles (BIC = -468.2). The ICL was also maximized for models VVI and VVV with 2 profiles. It should be noted that a couple of models could not be

estimated, specifically 9-profile models of type VVV and VVI. The optimal model (VVI with 2 profiles) showed acceptable average latent posterior probabilities (> 0.9). The *estimate_profiles* function from *tidyLPA* confirmed that, according to the majority rule (i.e., number of optimized indices), VVI with 2 profiles was the optimal model.

The profiles generated had sizes 13 and 55, and the first profile was characterized by having lower median values in both than the second profile (eye contact duration: $Mdn_1 = 0.4$, $Mdn_2 = 15$; proportion of attention: $Mdn_1 = .01$, $Mdn_2 = .15$) (see Figure 3.13). This solution was not equivalent to the 2-cluster solution; in this case both variables discriminated between profiles (eye contact duration: $U = 33.5$, $p < .001$, rank-biserial correlation = $.91$; proportion of attention: $U = 116$, $p < .001$, rank-biserial correlation = $.68$; Mann-Whitney). We found a significant difference between profiles in the duration of proximity in phase 1 of the sociability test ($M_1 = 18.18$, $M_2 = 30.45$, Student's $t(56) = -2.09$, $p = .042$, Cohen's $d = -0.76$).

Figure 3.13

Boxplots of the VVI 2-profile solution

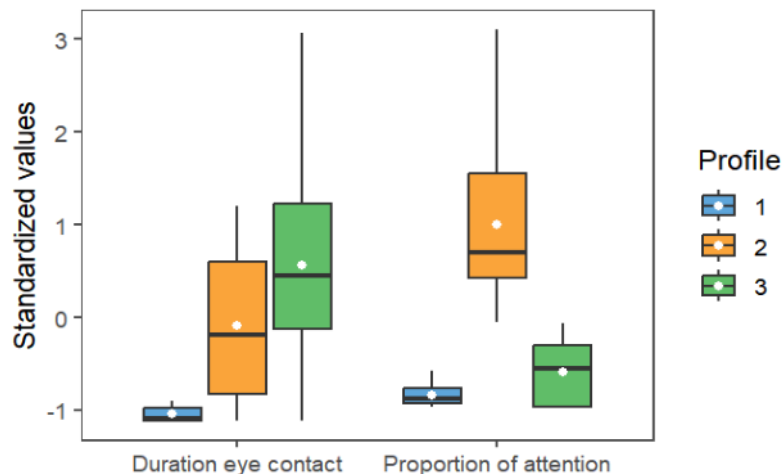


Note. The boxplots show the distribution of the indicator variables for the two profiles of the VVI model. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles).

We explored alternative solutions, starting with VVI with 3 profiles, since it was on the top 3 models according to the BIC criterion. This model had acceptable average latent posterior probabilities (> 0.8 , except profile 3 which had 0.79) and generated profiles of sizes 13, 27 and 28 that were equivalent in their interpretation to the clusters obtained in the traditional CA (see Figure 3.14). When examining the composition of the profiles and the clusters, it differed considerably. While Profile 1 had only individuals from the Low Orienting cluster, in profile 2 48% individuals were from Low Orienting, 44% from High Attention and 7% from Adaptable Orienting, and in profile 3 57% individuals were from Low Orienting and 43% from Adaptable Orienting. The difference in relative synchronization found in the CA solution was no longer present in the LPA solution and no differences in DPQ scores, nor variables from the other social motivation tests, the sociability and social cognition tests were found. Overall, the LPA seems to have generated less distinct groups, but agrees with the CA solution in the identification of three patterns and their characterization.

Figure 3.14

Boxplots of the VVI 3-profile solution



Note. The boxplots show the distribution of the indicator variables for the three profiles of the VVI model. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes) and lowest and highest cases within 1.5 times the interquartile range (whiskers)

3.5.2.3. *Proportion of attention towards humans and proportion of social play*

3.5.2.3.1. *Cluster analysis*

Then we used as clustering variables only the proportion of attention from the unsolvable task and the average proportion of social play from the play test. We checked for outliers computing Mahalanobis distance and three cases were removed ($n = 45$). A Hopkins statistic value of 0.53 suggested it was clusterable.

We considered the use of both hierarchical (agglomerative) and non-hierarchical (k-means) clustering methods, using the same procedure as above. Comparison of internal validation measures (connectivity, Dunn and silhouette indices) did not provide a clear answer but suggested that average or complete algorithms might be the best options. Examination of the correlation between the cophenetic distance and the original distance for the three linkage methods confirmed that the average algorithm and complete algorithms were more accurate than Ward. Although no linkage method reached a correlation value of 0.75, the average method was close (0.73). Even if the complete algorithm had a lower value (0.67), we decided to not discard this method yet. Therefore, we explored solutions using both algorithms in the following steps.

As before, we used the *NbClust* function to determine the optimal number of clusters. The majority rule suggested a 3-cluster solution for the agglomerative hierarchical method with both average and complete linkage and for the k-means method. These are the solutions we considered in the next steps.

Comparison of internal validation measures (connectivity, Dunn and silhouette indices) showed that the 3-cluster solution with k-means was inferior to the solution with average linkage in the three indices and was only superior to the complete linkage solution regarding the silhouette index. Still, we decided to keep exploring the k-means solution. The solution with complete linkage was only superior to the solution with average in the connectivity index but they had similar values in the Dunn index, so we continued working with this solution too. Examination of the silhouette plot revealed only one observation with a negative silhouette index in the three solutions.

The 3-cluster solution using the agglomerative hierarchical method with average linkage generated clusters of sizes 27, 8 and 10. The first cluster was characterized by having a low mean proportion of attention but a high mean average proportion of social play. The mean values of the second cluster in both variables were below average, with the mean proportion of social play being the lowest of the three clusters. Contrarily, the mean values of the third cluster in both variables were above average, and this cluster had the highest mean proportion of attention (see Figure 3.15, Figure 3.16 and Table A.28). The clusters differed significantly in both variables (proportion of attention: Welch's $F(2, 14) = 29.9, p < .001$; proportion of social play: $F(2, 42) = 33.4, p < .001, \eta^2 = .61$), but pairwise comparisons revealed that it was cluster 3 that differed from 1 and 2 in the proportion of attention (clusters 1-3: $t(11.7) = -7.85, p < .001$; clusters 2-3: $t(15.8) = -6.48, p < .001$; Games-Howell's post-hoc test), and cluster 2 was significantly different from 1 and 3 in the average proportion of social play (clusters 1-2: $t(42) = 7.62, p < .001$; clusters 2-3: $t(42) = -7.23, p < .001$; Tukey's post-hoc test).

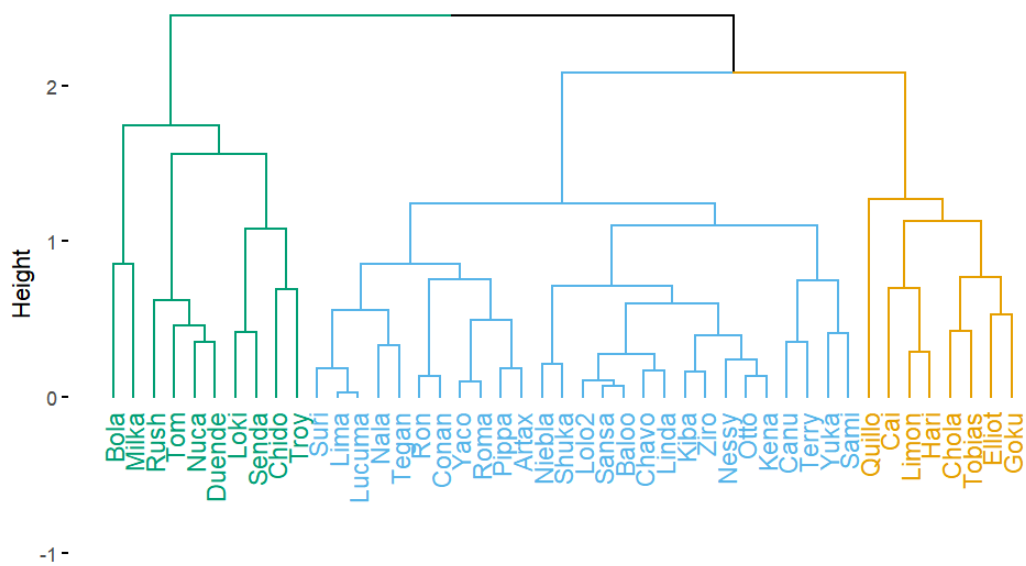
Therefore, individuals from cluster 1 showed low social orienting (mean proportion of attention below average) but high social reward (mean values of average proportion of social play above average) (i.e., Low Orienting – High Reward cluster). While individuals from cluster 2 displayed low social motivation in both tests (i.e., Low Social Motivation cluster), individuals from cluster 3 showed high social motivation in both contexts (i.e., High Social Motivation cluster). However, no significant differences between clusters in DPQ scores, demographic variables, nor variables from the other social motivation tests, the sociability and social cognition tests were found.

The 3-cluster solution using the agglomerative hierarchical method with complete linkage resulted in clusters of sizes 29, 10 and 6. Cluster 1 from the complete linkage solution was equivalent to cluster Low Orienting – High Reward, plus three individuals from cluster High Social Motivation. Cluster 2 was equivalent to cluster Low Social Motivation, plus two individuals from Low Orienting – High Reward. Lastly, all individuals from cluster 3 belonged to the High Social Motivation cluster. Therefore, the characteristic attributes of the clusters were the same as in the previous solution. The difference between clusters in the two variables was significant (proportion of attention: $\chi^2 = 15.1, p < .001, \epsilon^2 = .34$; proportion of social play: $\chi^2 = 22.6, p < .001, \epsilon^2 = .51$; Kruskal-Wallis), indicating that both were contributing to the distinctiveness of the clusters in this solution as well. Pairwise comparisons revealed a similar picture as before; hence,

interpretation of the profiles of individuals belonging to each cluster would be the same as in the average linkage solution. When exploring differences between the clusters in variables from the other social motivation tests, no significant differences between clusters in DPQ scores, demographic variables, nor variables from the other social motivation tests, the sociability and social cognition tests were found.

Figure 3.15

Dendrogram of the 3-cluster hierarchical solution with average linkage



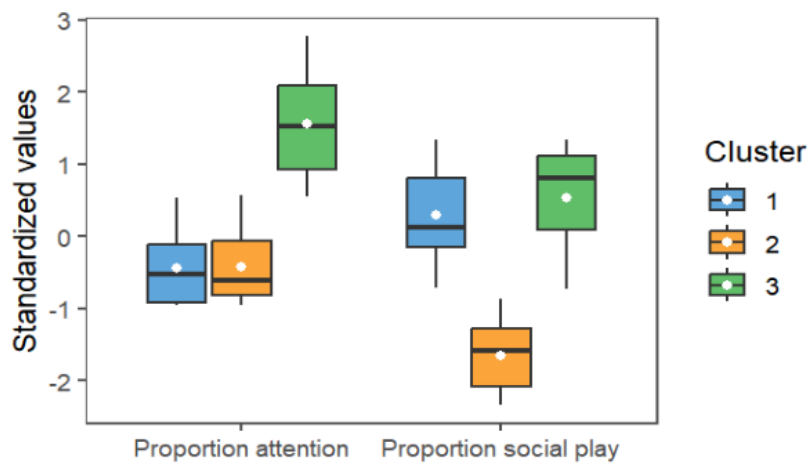
Note. Graphical representation of the hierarchical clustering with average linkage with proportion of attention towards humans and proportion of social play as clustering variables. The dendrogram shows how the subjects are grouped at each step of the procedure, starting with each individual as a separate cluster at the bottom of the graph and ending with all individuals in a single cluster at the top. The y-axis represents the height of the branch points, which indicates the dissimilarity between the clusters. The colours represent the 3-cluster solution.

The 3-cluster solution with k-means generated clusters of sizes 10, 9 and 26. Cluster 1 was equivalent to cluster High Social Motivation and cluster 3 was equivalent to cluster Low Orienting – High Reward. Cluster 2 was analogous to cluster Low Social Motivation plus an individual from Low Orienting – High Reward. Therefore, this solution was practically identical to the solution with average linkage. Expectedly, no

significant differences between clusters in DPQ scores, demographic variables, nor variables from the other social motivation tests, the sociability and social cognition tests were found.

Figure 3.16

Boxplots of the 3-cluster hierarchical solution with average linkage



Note. The boxplots show the distribution of the clustering variables for the three clusters obtained through hierarchical clustering with average linkage. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes) and lowest and highest cases within 1.5 times the interquartile range (whiskers). Cluster 1 = Low Orienting – High Reward; cluster 2 = Low Social Motivation; cluster 3 = High Social Motivation

3.5.2.3.2. Latent profile analysis

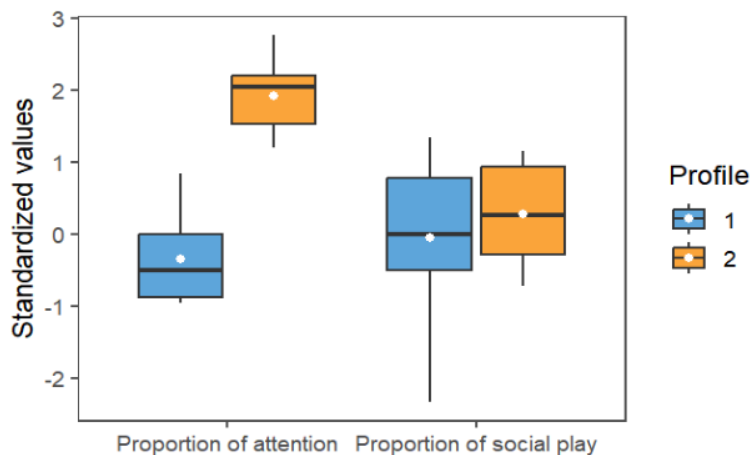
The *mclust* function indicated that the top 3 models based on the BIC criterion were (1) EEI with 2 profiles (BIC = 57.5), (2) VVI with 2 profiles (BIC = 54.1) and (3) EEI with 3 profiles (BIC = 52.2). The ICL was also maximized for model EEI with 2 profiles. It should be noted that a couple of models could not be estimated, specifically the 8 and 9-profile models of type VVV. The optimal model (EEI with 2 profiles) showed acceptable average latent posterior probabilities (> 0.9). The *estimate_profiles* function from *tidyLPA* confirmed that, according to the majority rule (i.e., number of optimized

indices), EEI with 2 profiles was one of the most optimal models (tied with 9-profile VVI).

The profiles generated had sizes 38 and 7, and the first profile was characterized by having lower mean values in both variables (duration of eye contact and proportion of attention) than the second profile (see Figure 3.17). However, only the proportion of attention was discriminating between profiles. Given that the 2-profile solution didn't seem very informative, we explored alternative solutions, starting with 3-profiles solutions to compare them to the CA solution.

Figure 3.17

Boxplots of the EEI 2-profile solution



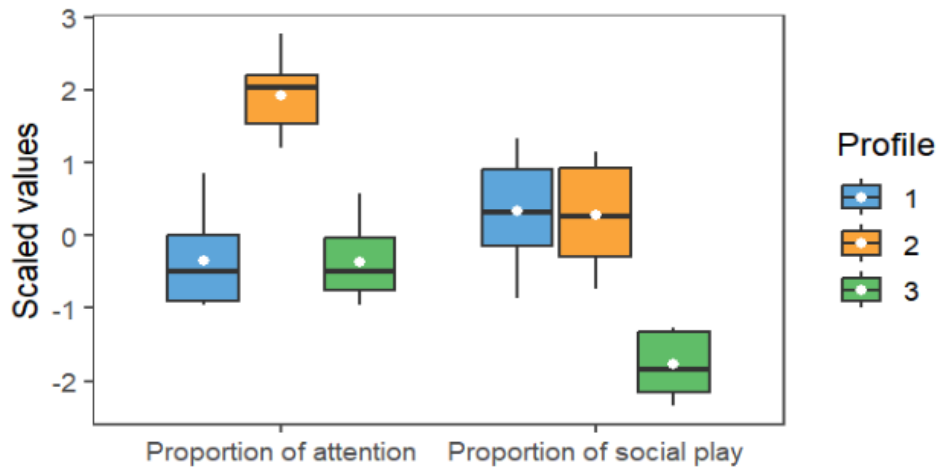
Note. The boxplots show the distribution of the indicator variables for the two profiles of the EEI model. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes) and lowest and highest cases within 1.5 times the interquartile range (whiskers).

Three-profile EEI was in the top 3 according to the BIC criterion. This model had acceptable average latent posterior probabilities (> 0.9) and generated profiles of sizes 31, 7 and 7 that were equivalent in their interpretation to the clusters obtained in the traditional CA (see Figure 3.18). The composition of the profiles and the clusters was similar. Profile 1 was analogous to cluster Low Orienting – High Reward, plus one

individual from Low Social Motivation and three from High Social Motivation. All individuals from profile 2 belonged to cluster High Social Motivation, and all individuals from profile 3 were assigned to cluster Low Social Motivation. Expectedly, no differences in DPQ scores, nor variables from the other social motivation tests, the sociability and social cognition tests were found. Overall, through LPA we arrived at a solution that was highly similar to the one selected in CA.

Figure 3.18

Boxplots of the EEI 3-profile solution



Note. The boxplots show the distribution of the indicator variables for the three profiles of the EEI model. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes) and lowest and highest cases within 1.5 times the interquartile range (whiskers).

3.5.2.4. *Eye contact duration and proportion of social play*

3.5.2.4.1. *Cluster analysis*

Lastly, we used as clustering variables only the duration variable from the eye contact test and the average proportion of social play from the play test. We checked for

outliers computing Mahalanobis distance and no cases were removed ($n = 55$). A Hopkins statistic value of 0.61 suggested that the data was clusterable.

As before, we considered the use of both hierarchical (agglomerative) and non-hierarchical (k-means) clustering methods. Comparison of internal validation measures (connectivity, Dunn and silhouette indices) did not provide a clear answer but suggested that the complete and average algorithms were superior to Ward. Examination of the correlation between the cophenetic distance and the original distance for the three linkage methods showed that the complete and Ward algorithms were similar in accuracy, while the average algorithm had the highest value. Although no linkage method reached a correlation value of 0.75, the average method was close (0.72). Even if the complete algorithm had a lower value (0.67), we decided to not discard this method yet. Therefore, we explored solutions using both algorithms in the following steps.

As above, to determine the optimal number of clusters we used the *NbClust* function. The majority rule suggested a 3-cluster solution for the agglomerative hierarchical method with average linkage and for the k-means method, while it proposed a 2-cluster solution (closely followed by a 4-cluster solution) with the complete linkage algorithm. Consequently, we considered a 3-cluster solution with average and k-means, and 2-cluster and 4-cluster solutions with complete algorithm in the next steps.

Comparison of internal validation measures (connectivity, Dunn and silhouette indices) showed that the 3-cluster solution with k-means was inferior to the solution with the average algorithm, except for the silhouette index. This solution was also inferior to both the 2 and the 4-cluster solution with complete linkage in the three indices, which suggested that it could be discarded. Still, we decided to keep exploring it in the next steps. The 3-cluster solution with the average algorithm was superior to the 2-cluster solution with complete linkage in the Dunn and silhouette indices but was inferior to the 4-cluster solution in the three indices. Examination of the silhouette plot revealed that the 3-cluster hierarchical solution had four observations with a negative silhouette index, while the solution with k-means only had one. The 2-cluster solution with complete linkage had one, and the 4-cluster solution had two. We decided to continue exploring all these solutions in the subsequent steps.

The 2-cluster solution using the agglomerative hierarchical method with complete linkage generated clusters of sizes 22 and 33. The first cluster had a higher mean eye

contact duration than the second one, but there was no significant difference in the average proportion of social play, indicating that this variable was not contributing to the distinctiveness of the clusters. For this reason, this cluster solution was discarded.

In the 3-cluster solution from both the hierarchical and the k-means methods, there was a significant difference between the clusters in both variables (hierarchical solution - eye contact duration: $\chi^2 = 23.1, p < .001, \varepsilon^2 = .43$, Kruskal-Wallis; proportion of social play: $\chi^2 = 30.7, p < .001, \varepsilon^2 = .57$, Kruskal-Wallis; k-means solution - eye contact duration: $\chi^2 = 32.4, p < .001, \varepsilon^2 = .6$, Kruskal-Wallis; proportion of social play: Welch's $F(2, 23.4) = 64.4, p < .001$), confirming that both were contributing to the distinctiveness of the clusters. However, pairwise comparisons suggested that the hierarchical solution was more successful in obtaining more distinct clusters. While both solutions had one cluster that differed significantly from the others in the eye contact variable, only the hierarchical solution had the three clusters differing significantly from each other in the play test variable. Thus, we discuss only the hierarchical solution next.

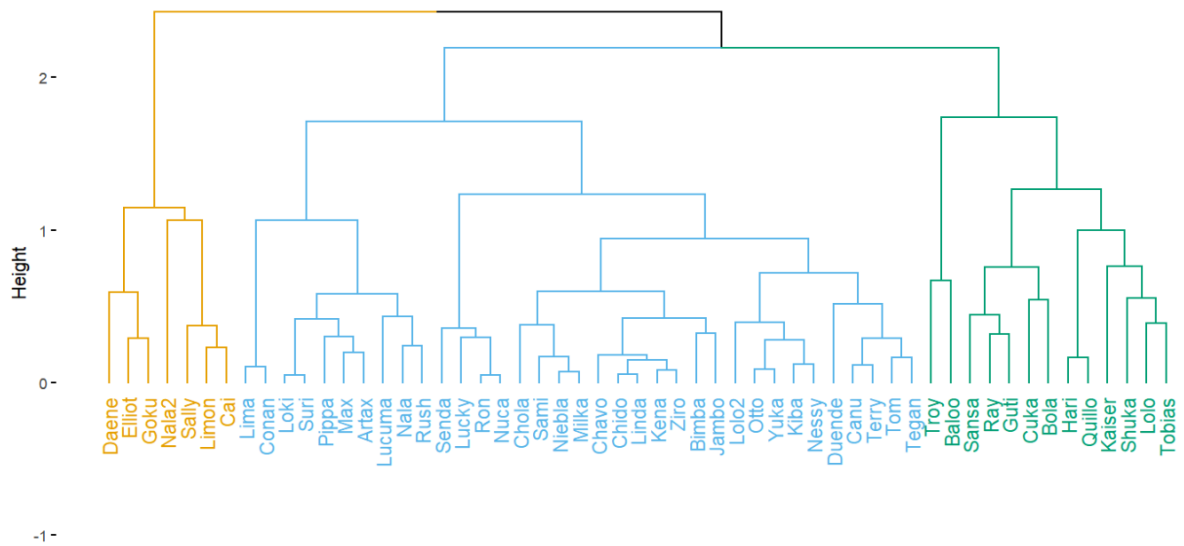
Clusters of sizes 35, 7 and 13 were generated. Cluster 1 had the highest mean average proportion of social play, while cluster 2 had the lowest; cluster 3 had the highest mean eye contact duration, while cluster 2 had the lowest (see Figure 3.19, Figure 3.20 and Table A.29). Cluster 3 differed significantly from clusters 1 and 2 in the duration of eye contact (clusters 1-3: $W = 6.3, p < .001$; clusters 2-3: $W = 5.10, p < .001$; DSCF). As previously mentioned, the three clusters differed in the distribution of the average proportion of social play, with cluster 1 having the highest values, cluster 2 the lowest and cluster 3 intermediate (clusters 1-2: $W = -5.85, p < .001$; clusters 1-3: $W = -5.92, p < .001$; clusters 2-3: $W = 4.31, p = .006$; DSCF).

Therefore, dogs from cluster 2 had a low social motivation in both tests; hence, we denominated this cluster Low Social Motivation. Dogs from cluster 1 had a low mean duration of eye contact (i.e., low social orienting), but had the highest average proportion of social play (i.e., high social reward). Thus, this cluster could be called Low Orienting – High Reward. Finally, dogs from cluster 3 showed a high duration of eye contact (i.e., high social orienting), but were at the intermediate level regarding the average proportion of social play. This cluster was therefore named High Orienting. It could be hypothesized that individuals from the High Orienting cluster established eye contact as a strategy to obtain the food but were not that interested in actually interacting with the experimenter. Dogs from cluster Low Orienting – High Reward, on the other hand, were interested in

interacting with the experimenter during the play test but didn't have a long duration of eye contact. This shorter duration compared to cluster High Orienting could be due to a lower motivation to obtain the food reward or a lower persistence, or on the contrary could imply that these individuals were too fixated on the food reward (i.e., they spent most of the trial looking at the container instead of the experimenter). Nevertheless, no significant differences between clusters in DPQ scores, demographic variables, nor variables from the other social motivation tests, the sociability and social cognition tests were found.

Figure 3.19

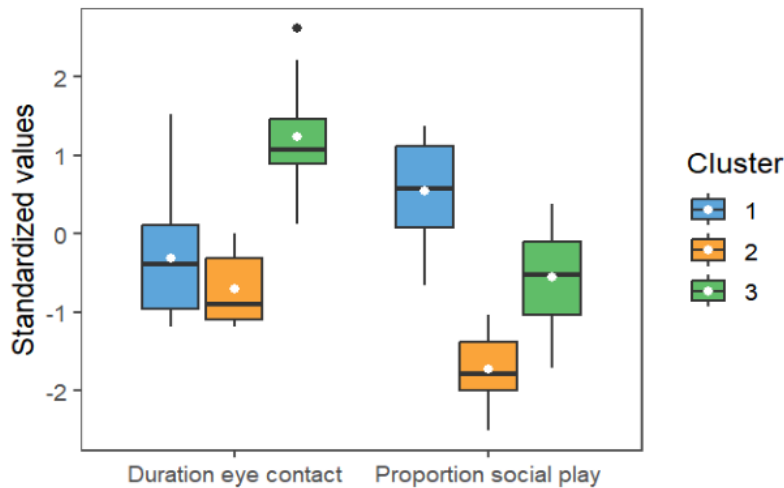
Dendrogram of the 3-cluster hierarchical solution with average linkage



Note. Graphical representation of the hierarchical clustering with average linkage with eye contact duration and proportion of social play as clustering variables. The dendrogram shows how the subjects are grouped at each step of the procedure, starting with each individual as a separate cluster at the bottom of the graph and ending with all individuals in a single cluster at the top. The y-axis represents the height of the branch points, which indicates the dissimilarity between the clusters. The colours represent the 3-cluster solution.

Figure 3.20

Boxplots of the 3-cluster hierarchical solution



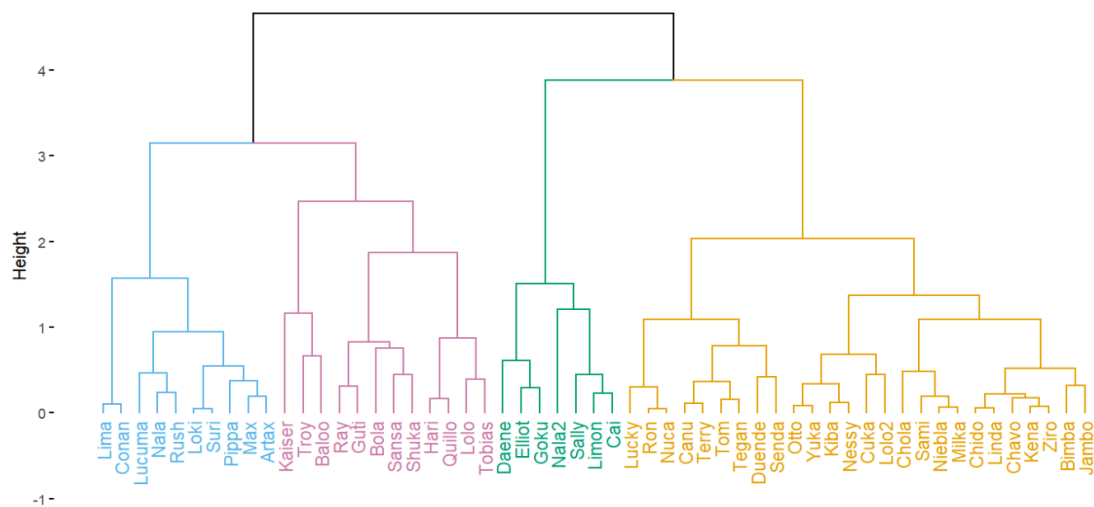
Note. The boxplots show the distribution of the clustering variables for the three clusters obtained through hierarchical clustering with average linkage. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles). Cluster 1 = Low Orienting – High Reward; cluster 2 = Low Social Motivation; cluster 3 = High Orienting

The 4-cluster solution generated clusters of sizes 10, 26, 7 and 12. In this solution, subjects from the cluster Low Orienting – High Reward were split into two clusters, with 29% going to cluster 1 and 71% to cluster 2. Individuals from the Low Social Motivation cluster remained together, being placed into cluster 3. Similarly, all individuals from cluster High Orienting went together into cluster 4 (except for one individual who was placed in cluster 2). Cluster 1 was mainly characterized by having the highest mean average proportion of social play, cluster 2 had a low mean eye contact duration but a high mean on the play test variable, cluster 3 had low mean values in both and was the group with the lowest mean average proportion of social play, and cluster 4 had the highest mean duration of eye contact (see Figure 3.21, Figure 3.22 and Table A.30). Statistical tests confirmed that the clusters differed significantly in the distribution of both

variables (eye contact duration: $\chi^2 = 39.4, p < .001, \epsilon^2 = .73$, Kruskal-Wallis; proportion of social play: Welch's $F(3, 19) = 76.9, p < .001$). DSCF pairwise comparisons revealed that clusters 1 and 4, and clusters 2 and 3 were not significantly different from each other in the duration of eye contact, and the former (1 and 4) had higher values than the latter (2 and 3) (comparison cluster 1-2: $W = -6.45, p < .001$; clusters 1-3: $W = -4.69, p = .005$; clusters 2-4: $W = 6.93, p < .001$; clusters 3-4: $W = 5.02, p = .002$). On the other hand, the four clusters were significantly different from each other in the average proportion of social play (cluster 1 > 2 > 4 > 3) (clusters 1-2: $t(33.6) = 5.93, p < .001$; clusters 1-3: $t(7.12) = 13.65, p < .001$; clusters 1-4: $t(13.1) = 8.23, p < .001$; clusters 2-3: $t(10.37) = 9.01, p < .001$; clusters 2-4: $t(19) = 4.02, p = .004$; clusters 3-4: $t(15.3) = -4.18, p = .004$; Games-Howell's post-hoc test). Therefore, in this solution the average proportion of social play allowed a more nuanced discrimination of clusters.

Figure 3.21

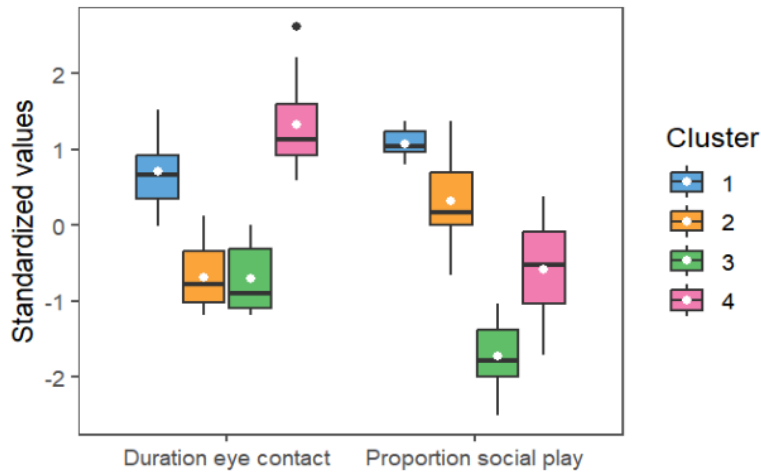
Dendrogram of the 4-cluster hierarchical solution with complete linkage



Note. Graphical representation of the hierarchical clustering with complete linkage with eye contact duration and proportion of social play as clustering variables. The dendrogram shows how the subjects are grouped at each step of the procedure, starting with each individual as a separate cluster at the bottom of the graph and ending with all individuals in a single cluster at the top. The y-axis represents the height of the branch points, which indicates the dissimilarity between the clusters. The colours represent the 4-cluster solution.

Figure 3.22

Boxplots of the 4-cluster hierarchical solution



Note. The boxplots show the distribution of the clustering variables for the four clusters obtained through hierarchical clustering with complete linkage. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles). Cluster 1 = High Social Motivation; cluster 2 = Low Orienting – High Reward; cluster 3 = Low Social Motivation; cluster 4 = High Orienting – Low Reward.

Although dogs from clusters 1 and 4 are similar to each other in terms of the duration of eye contact (i.e., similar social orienting), dogs from cluster 1 had a higher average proportion of social play (i.e., higher social reward). Individuals belonging to cluster 1, thus, showed a high social motivation in both contexts, so this cluster was denominated High Social Motivation. Since cluster 4 had the highest mean duration of eye contact but values below average in the average proportion of social play, it was labelled High Orienting – Low Reward. Dogs from cluster 2 and 3 also had similar values in the eye contact variable, but individuals from cluster 2 had a superior average proportion of social play. So, cluster 3 dogs showed a low social motivation in both contexts, and this cluster was called Low Social Motivation. Since cluster 2 had values below average in the eye contact duration but values above average in the average

proportion of social play, it was labelled Low Orienting – High Reward. However, no significant differences between clusters in DPQ scores, variables from the other social motivation tests, nor the sociability and social cognition tests were found.

3.5.2.4.2. Latent profile analysis

The initial optimal model indicated by *mclust* function had only one profile. This might be related to a Hopkins statistic value of 0.61, which is not too high, although in the previous analysis of a dataset with a Hopkins statistic of 0.53 a one-profile model was not suggested by LPA. Although this implied that there might not be clusters/profiles in this dataset, we excluded the 1-profile models and explored further solutions. The top 3 models based on the BIC criterion were (1) EEE with 2 profiles (BIC = -447.2), (2) VVI with 2 profiles (BIC = -450.9) and (3) EEI with 2 profiles (BIC = -451.4). The ICL was also maximized for models EEI and VVI with 2 profiles, with EEE and VVV close behind. We prioritized the BIC criterion and chose EEE with 2 profiles as the optimal model. It showed acceptable average latent posterior probabilities (> 0.9). The *estimate_profiles* function from *tidyLPA* confirmed that, according to the majority rule (i.e., number of optimized indices), EEE with 2 profiles was one of the most optimal models (tied with 9-profile EEE). However, we only compared model types EEI and EEE, since when we tried to run the function including the four model types it never stopped running.

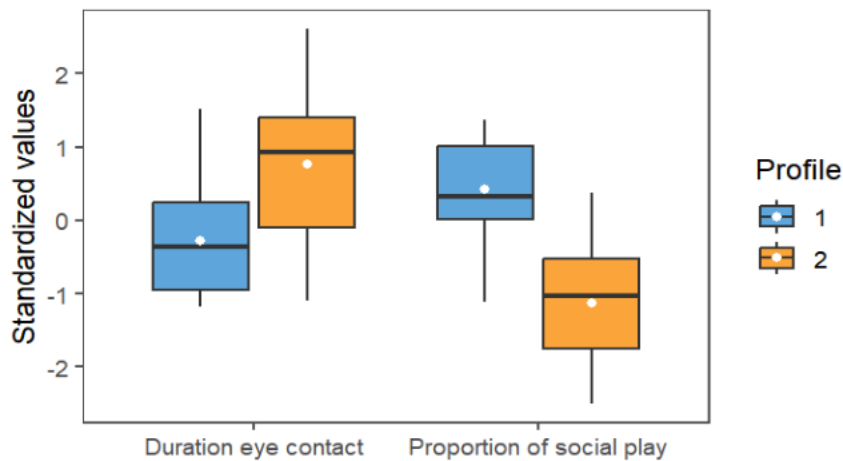
The profiles generated had sizes 40 and 15, and the first profile was characterized by having higher mean in the average proportion of social play than the second profile, but a lower mean duration of eye contact (see Figure 3.23). This solution was not equivalent to the 2-cluster solution; in this case both variables discriminated between profiles (eye contact duration: Student's $t(53) = -3.9, p < .001$, Cohen's $d = -1.18$; proportion of social play: $t(53) = 7.11, p < .001$, Cohen's $d = 2.15$). Moreover, we found a significant difference between profiles in the duration of proximity (Student's $t(49) = -2.14, p = .038$, Cohen's $d = -0.66$) and of physical contact (Welch's $t(18.47) = -2.2, p = .04$, Cohen's $d = -0.74$) during phase 1 of the sociability test.

We explored alternative solutions, starting with 3-profile solutions to compare them to the CA solution. According to the BIC criterion, the best 3-profile model was

VVI. This model had acceptable average latent posterior probabilities (> 0.8) and generated profiles of sizes 17, 27 and 11. The profiles were not equivalent in their interpretation to the clusters obtained in the traditional CA and their composition was different. In this solution, profiles 1 and 3 were parallel, which means that they only differed quantitatively but showed the same pattern (i.e., higher mean in the play test than in the eye contact test) (see Figure 3.24).

Figure 3.23

Boxplots of the EEE 2-profile solution



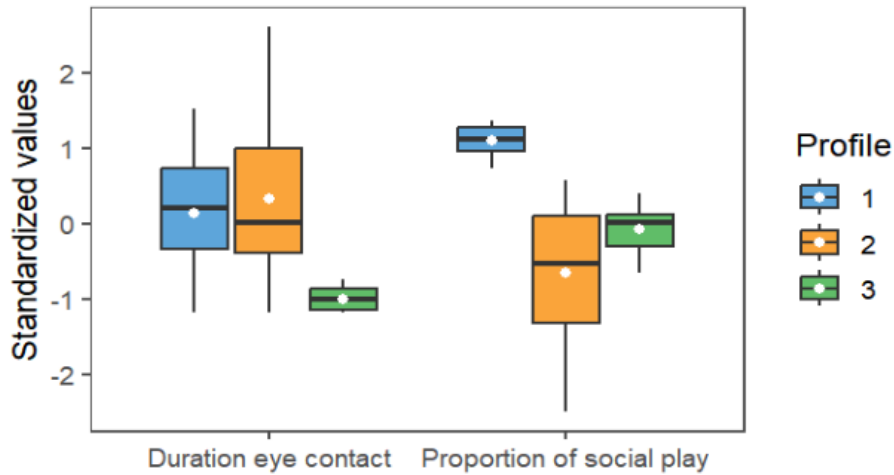
Note. The boxplots show the distribution of the indicator variables for the two profiles of the EEE model. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes) and lowest and highest cases within 1.5 times the interquartile range (whiskers).

We also sought a 4-profile solution that we could compare to the CA solution. According to the BIC criterion, the best 4-profile model was VVI. This model had acceptable average latent posterior probabilities (> 0.8) and generated profiles of sizes 19, 3, 17 and 16. Again, the profiles were not equivalent in their interpretation to the clusters obtained in the traditional CA (see Figure 3.25) and their composition was different. This solution was like the 3-profile solution with one additional profile which was parallel to an existing one. Profiles 1 and 4, and profiles 2 and 3 were parallel to each

other. This, in addition to the small size of one of the profiles ($n = 3$), suggested that this solution was not optimal.

Figure 3.24

Boxplots of the VVI 3-profile solution



Note. The boxplots show the distribution of the indicator variables for the three profiles of the VVI model. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes) and lowest and highest cases within 1.5 times the interquartile range (whiskers).

Overall, we didn't obtain equivalent solutions with LPA and traditional CA, which decreases our confidence about the generated clusters. Although it seems that generally CA created more distinct clusters (i.e., LPA created parallel profiles, which only differed quantitatively), the 2-profile solution was the only one for which we found evidence of criterion or predictive validity (i.e., differences between profiles in sociability variables).

Figure 3.25

Boxplots of the VVI 4-profile solution



Note. The boxplots show the distribution of the indicator variables for the four profiles of the VVI model. The data of each variable is standardized (subtracting the mean and dividing by the standard deviation). Values represented are means (white circles), medians (thick line within boxes), 25th and 75th percentiles (borders of boxes), lowest and highest cases within 1.5 times the interquartile range (whiskers) and outliers (black circles).

3.6. ADDITIONAL ANALYSES

Regarding sex, we didn't find differences between males and females in any variable. When considering the reproductive status, we only found that intact males had significantly higher scores in Responsiveness to Training than neutered females (Welch's $F(3, 36.8) = 3.6, p = .022$; intact males: $n = 19, M = 22.6$, neutered females: $n = 41, M = 19.5$, Games-Howell post-hoc test: $t(37) = 3.03, p = .022$).

Regarding age, we found significant correlations between age in years and the average duration of proximity to the experimenter in the play test (Kendall rank correlation, $\tau(75) = -.246, p = .002$), the proportion of trials the subject chose the large amount of food in the conformity test ($\tau(41) = -.247, p = .038$), and the gaze score in the food begging test ($\tau(80) = .181, p = .047$). There was also a significant correlation with the Activity/Excitability factor from the personality questionnaire ($\tau(102) = -.35, p < .001$).

CHAPTER 4 – DISCUSSION AND CONCLUSIONS

4.1. BEHAVIOURAL MANIFESTATIONS OF SOCIAL MOTIVATION

In our first hypothesis, we aimed to test whether the three theoretical categories proposed by Chevallier et al. (2012), i.e., social orienting, social reward, and social maintaining, could be identified empirically. However, the pattern of correlations between the variables of the social motivation tests rendered a factor analysis unfeasible and did not support the existence of three different dimensions. Thus, we only examined the correlations between social motivation tests, across and within the three theoretical categories. Only a few significant correlations between tests emerged, and they were weak to moderate in size at best (see Table 3.1), with some going in the opposite direction to what we predicted. Moreover, the correlations between variables of the social motivation tests were not higher overall than correlations with tests of other constructs (i.e., sociability, social cognition), providing little evidence of discriminant validity.

Individuals that established eye contact for a longer duration during the eye contact (EC) test had a shorter latency to gaze at the humans during the unsolvable task (UT). This is consistent with our expectations, given that both variables were interpreted as measures of social orienting. Given that both tests presented a similar situation, in which there was a food reward that was unobtainable and a human was present, these variables could be taken as indicators of dogs' leaning towards human-oriented social strategies when facing a problem they are unable to solve (see also section 4.6.2.1 for different interpretations of behaviours in UT). Nevertheless, it should be mentioned that the relative latency to gaze at humans in the UT showed poor interobserver reliability (ICC = .53).

Contrary to our expectations, dogs that spent more time in proximity to the experimenter during the play test (i.e., higher social reward), took longer to gaze at the human during the UT (i.e., lower social orienting). However, there was no association between the latency to gaze at humans in the UT and the average proportion of social play. This implies that although dogs that had a higher latency to gaze at humans in the

UT spent more time close to the experimenter during the play test, they didn't necessarily play more with her (although proximity and proportion of social play were strongly correlated). In fact, this correlation might be linked to the dogs' food motivation. Given that the play test took place after one condition of the object choice task (OCT), which had a similar setting, some dogs that approached the experimenter during the play test might have been trying to obtain food. These subjects would also have been more focused on obtaining the food during the UT, hence taking longer to gaze at the humans. Again, the relative latency to gaze at humans in the UT showed poor interobserver reliability, so results should be interpreted with caution.

This negative association between gazing behaviour during the UT and proximity to the experimenter during the play test is in line with results of Turcsán et al. (2018) but stands in contrast to findings of MacLean et al. (2017). In the study by Turcsán and collaborators, an EFA grouped together components of a ball play test and a problem-solving task, but the signs of the components implied that there was a negative relationship between gaze alternations between ball and caregiver in the ball play test and the gaze duration towards humans in the problem-solving test. In the study by MacLean and coworkers, the duration of gazing to a human's face when presented with an unsolvable task and after the interruption of a social game both loaded positively onto the same factor. Thus, we checked whether the duration of gazing at the experimenter during the interruption period of our play test was associated with variables from the UT. Keeping only subjects that had data on gazing behaviour during four interruption trials in the play test, we didn't find any significant correlation with variables from the UT, but the sample size was small ($n = 11-12$) and duration of gazing during the interruption period was low overall.

Dogs that were more synchronized with their caregiver in terms of their activity (i.e., activity synchrony) were faster to alternate gaze between the apparatus and the humans during the UT. Thus, the direction of this correlation goes in the expected direction, since higher social orienting, indicated by a lower latency to alternate gaze, is associated with higher social maintaining, indicated by a higher relative synchronization. This suggests that dog-caregiver behavioural synchronization is related to communicative behaviours emitted during a problem-solving task. However, it should be noted that latency to gaze alternation in the UT had a relatively low interobserver reliability ($ICC = .65$).

Dogs that approached the caregiver more often after separation (after choosing food) were less likely to approach the social toy first, which does not fit with our view that both variables were indicators of social reward. A potential explanation is that dogs that approached the caregiver during reunion in the separation episodes (SE) were less likely to leave the caregiver during the play test. However, given that we only included in the analyses subjects that approached one of the toys, this explanation is discarded since these subjects were willing to leave the caregiver's side. Another possibility is that dogs that approached the caregiver more often were less willing to stay near the experimenter during the separation episodes and during the play test. This seems unlikely and is not supported given the lack of correlation found between the frequency of approaching the caregiver after separation and the duration of proximity to the experimenter during the play test.

Dogs that approached the caregiver more often (after choosing food) during reunion in the SE (i.e., high social reward) were more synchronized with their caregiver (i.e., high social maintaining), which fits our expectations. Apart from measuring social motivation, both variables might be related to the dog-caregiver bond. This association is in line with results from Brown (2019), since the correlation matrices from her study apparently show a very weak-weak positive correlation between synchronicity and orienting behaviour during a reunion test, as well as with the efficacy of social reinforcers (i.e., an indicator of social reward).

Finally, dogs that were more synchronized with their caregiver chose the large quantity less often in the conformity test, which means that they chose the plate favoured by the experimenter more frequently. Since a high relative synchronization and choosing the large quantity in the test in a low proportion of trials were both indicators of high social maintaining for us, this association agrees with our conceptualization. Therefore, the degree of dog-caregiver behavioural synchronization might be linked to the dogs' tendency to conform to human choices.

4.2. ASSOCIATIONS BETWEEN SOCIAL MOTIVATION AND SOCIABILITY

In our second hypothesis, the goal was to find out whether there was a positive association between social motivation and sociability. Thus, we examined the correlations between variables from the social motivation tests and variables from the sociability test. We found limited evidence of an association between presumed behavioural manifestations of social motivation and behaviours during the sociability test. Only two social motivation tests had significant correlations with variables from the sociability test: the eye contact and the play tests (see Table 3.2).

Dogs that took longer to establish physical contact with the experimenter during the sociability test had a shorter duration of eye contact during the EC test. This association goes in the expected direction and is in line with findings from previous studies which suggested that sociability levels might be related to social orienting in dogs (see section 1.5.1.3.1). In particular, results from Jakovcevic et al. (2012) and Putrino et al. (2014) showed an association between variables from a sociability test and gaze duration. Jakovcevic and collaborators only found one significant correlation between variables from the sociability test and duration of eye contact in a communicative learning task. In this task, dogs were initially reinforced for gazing at the experimenter (i.e., acquisition trials) and then experienced three extinction trials (i.e., no reward was delivered). Duration of physical contact with the experimenter during the passive phase of the sociability test correlated with gaze duration in the first extinction trial of the communicative task (Spearman's rank correlation, $r_s = .36$).

The sociability and especially the EC test in our study, however, were more similar to those used by Putrino et al. (2014), who found correlations between the duration of eye contact and the latency to proximity, latency to physical contact and duration of proximity to the experimenter from the sociability test. Regarding the variable "latency to proximity", we discarded it in our study since it was highly skewed and showed a low degree of variability. Finally, that we failed to find a correlation with duration of proximity might be explained by methodological differences, which might have limited the variability detectable in our sample, affecting the correlational analyses (see section 4.6.3). First, our tests had shorter phases, lasting 1 minute each instead of 2 minutes. Second, in our study during the active phase of the sociability test the experimenter knelt,

while in the other study she was standing. We assume that the duration of proximity variable the authors mention is the sum of the proximity in both phases, given that they don't specify. Recently, it has been emphasized how minor procedural variations, including the posture of the experimenter, affect dogs' behaviours during sociability assessments (Brown et al., 2020). What is more relevant in the present discussion is that Brown and collaborators found that dogs expressed more sociable behaviours when the experimenter was kneeling compared to when she was standing. Therefore, in our study the combination of a shorter phase 2 with a kneeling experimenter might have limited the individual variability. In any case, our results provide further evidence that there might be a relationship between dogs' sociability levels and their social orienting.

We also found that dogs that spent more time close to and in contact with the experimenter during the active phase of the sociability test chose more frequently to interact first with the social toy during the play test. According to our conceptualization, this suggests an association between sociability and social reward. This result is similar to findings reported by Bray et al. (2017) and Turcsán et al. (2018), which showed that variables from a ball play test (which were taken as measures of the dogs' willingness to play fetch or their playfulness) grouped together with variables from a greeting test with an unfamiliar human. Nevertheless, in our study there was no association between sociability variables and the average proportion of social play. Hence, more sociable individuals apparently had a stronger tendency to interact with the social toy first but didn't necessarily spend a higher proportion of time playing with the experimenter than other dogs. The association between variables from the active phase of the sociability test and variables from the play test can be partly explained by situational similarities. In both cases, the experimenter was kneeling and the subject could approach her. However, there were also differences, such as the fact that during the sociability test the experimenter called the subject as soon as the phase started and when the subject went away, while in the play test, she remained passive and only moved the toy and talked to the subject if the animal approached. Moreover, there was no association between sociability variables and the number of trials the subject approached the social toy first, or the average duration of proximity to the experimenter. Therefore, the relationship between the sociability variables of the active phase and choosing to interact first with the social toy cannot be explained simply by a stronger tendency to approach and remain in proximity to the kneeling experimenter.

4.3. ASSOCIATIONS OF SOCIAL MOTIVATION AND SOCIABILITY WITH SOCIAL COGNITION

In the third hypothesis our purpose was to see if there was a positive association between social motivation/sociability and socio-cognitive abilities as predicted by the DS and proposed by the *emotional reactivity hypothesis*, among others. Therefore, we explored the correlations between performance in the socio-cognitive tests and variables from the social motivation and sociability tests. The only significant correlations we found were between performance in the tasks measuring sensitivity to visual attention (i.e., call and food begging tests) and variables from the play test (i.e., social reward) (see Table 3.3).

Dogs that had a higher score in the call test showed a lower average proportion of social play. In our view, higher scores in the call test indicated that subjects had a higher understanding of the caregiver's visual field, since they gazed at the caregiver's face in the back condition, that is, they positioned themselves in front of them to establish an interaction. In our study, proportion of social play was considered an indicator of social reward. Therefore, the relationship we found between the call test score and the average proportion of social play went in the opposite direction to our hypothesis, since it implied a negative association between socio-cognitive abilities and social motivation. Potential explanations for this unexpected finding might be related to the fact that the humans involved in each test were different and to alternative interpretations of performance in the call test and behaviours during the play test.

While both the experimenter and caregiver were present in both tests, the play test assessed interaction with the experimenter, while the call test assessed behaviours directed at the caregiver. Moreover, performance in the call test might not only be a measure of the dogs' socio-cognitive abilities, but also of their social motivation. Subjects that had higher call test scores might have a higher motivation to interact with the caregiver (enough to position themselves in front of the caregiver in the back condition) and hence be less willing to leave the caregiver's side during the play test. However, if this was the case, we would expect a negative association with the average duration of proximity to the experimenter during the play test.

Another possibility is that the average proportion of social play is not an indicator of social motivation, which is in line with the lack of significant correlations between this variable and variables from other social motivation tests. The average proportion of social play could instead be an indicator of playfulness. However, there was no significant correlation between this variable and the Activity/Excitability factor from the 5-factor model of our modified DPQ, and half of the items of this factor belonged to the Playfulness facet. Still, even if this variable reflected playfulness instead of social motivation, these constructs could be related (playfulness and sociability have been found to overlap on some occasions: e.g., Chapagain et al., 2020; Svartberg, 2006; Svartberg & Forkman, 2002; Turcsán et al., 2018, 2020), and we could also expect a positive association between playfulness and cognition. For example, gifted word learner Border collies were rated as more playful than typical Border collies (Fugazza et al., 2022). Nevertheless, different aspects of cognition are not necessarily related to one another, and even if playfulness is linked to word learning it might not be related to other cognitive abilities. Yet, a positive association between playfulness and understanding of visual fields seems plausible. On the other hand, sensitivity to cues of visual attention has sometimes been tested using a ball fetching task (Gácsi et al., 2004; Hare et al., 1998; E. L. MacLean et al., 2017). Presumably, subjects that participated in this test had to be playful. Thus, if there was a link between playfulness and sensitivity to visual attention, we would expect most of these subjects to be successful in these tests. On the contrary, Gácsi et al. (2004) found that they performed quite poorly in the back condition of the ball fetching task. Although they were more successful in object fetching tasks, there was still some variability.

A final consideration is how our call test score might be related to attentional state discrimination. An alternative interpretation of this test is that, if subjects are sensitive to cues denoting the attentional state of the caregiver, they might have interpreted that in the back condition the caregiver was unavailable. Typically, tests examining sensitivity to human attention in dogs present them with a choice between two humans who differ in their attentional state (e.g., facing the animal versus having their back turned to the animal). In these tests, if dogs are sensitive to cues of attentional states (e.g., body orientation) they are expected to show a discrimination between the two humans. In a cooperative context, such as food begging, usually the correct choice would be to beg from the human that is facing the animal and interpreting the other human as inattentive.

In our test the subjects didn't have to choose between two humans but were presented with a facing and a back condition. Subjects that didn't gaze at the caregiver's face in the back condition might have interpreted their body orientation as a signal of inattentiveness. However, in our test the caregiver called the subject by their name (i.e., an ostensive cue), thus giving a verbal indication of attentiveness and their willingness to establish an interaction with the animal. Still, given that they were faced with conflicting cues in the back condition (i.e., body orientation suggesting inattentiveness and verbal cue suggesting attentiveness), it is unclear how the subjects should have reacted (see also discussions in Udell & Wynne, 2011; Virányi & Range, 2011). Even with these caveats in mind, we would have expected more socially motivated animals to achieve a higher score in the test. That is, when faced with conflicting cues, subjects with a higher motivation to interact would show a bias towards cues indicative of the human's disposition for social interaction (i.e., the verbal cue) and, if they understood humans' visual fields or were sensitive to cues related to them, they would position themselves in a place where the interaction could happen (i.e., in front of the caregiver).

Dogs that approached the social toy first more often in the play test had higher success and gaze scores in the food begging tests. Higher success scores in the food begging test indicated that the subjects positioned themselves in front of the experimenter in the back condition, while gaze scores also took into account whether they gazed at the experimenter's face. Thus, as with the call test, higher scores in the food begging test were interpreted as a better understanding of the visual field of the experimenter. In this case, the relationship with the social motivation variable (i.e., number of trials the subject approached the social toy first, an indicator of social reward in our conceptualization) went in the expected direction. Interestingly, in this case both tests examined interactions with the experimenter. However, as with the call test, several interpretations of the food begging test are possible.

Firstly, one could interpret this positive association as an indication that individuals who find social interactions with humans more rewarding are better at understanding human's visual fields or more sensitive to cues related to them. This is the interpretation that is consistent with our conceptualization and our hypothesis. Secondly, as with the call test, it could be argued that scores in the food begging test also partially reflect social motivation, especially in the case of the gaze score. Indeed, in this test

subjects were presented with a situation that was similar to some extent to the eye contact test and the unsolvable task (i.e., unreachable food in the presence of a human).

Thirdly, behaviours in the food begging test might be related to differences in the food motivation of the subjects. Although all participants were food motivated, subjects that had higher scores, i.e., that positioned themselves in front of the experimenter in the back condition, could be the individuals that had higher food motivation (i.e., they were more motivated to beg for food). Alternatively, subjects that remained at the back of the experimenter when she turned around might have had such a strong food motivation that it prevented them from moving away from the food container to position themselves in front of the experimenter. However, if this was the case, these subjects might have followed the food container in the facing condition, therefore positioning themselves at the experimenter's back. This could be an explanation for the behaviour of the few subjects that received a score of 0 (i.e., they didn't stay at the experimenter's front in the facing condition and they stayed at the experimenter's back in the back condition).

Fourthly, as with the call test, we would have to consider the role of sensitivity to cues of attentional states in the scores of the food begging test. As was discussed earlier, a human that is facing away can be interpreted as inattentive. Moreover, in this test there was no ostensive cue and the dogs saw how the experimenter, who had just provided them with food, turned their back to them, which could be a signal of the end of the interaction. Thus, in this test the possibility that dogs interpreted the experimenter as inattentive or unavailable in the back condition seems more plausible. Still, dogs with a higher social (or food) motivation might be more persistent in trying to re-establish an interaction. That is, even if dogs interpreted the experimenter as inattentive in the back condition, individuals with a higher social motivation would attempt to re-gain this attention and re-establish the interaction. In order to do this, they would have to consider the visual field of the experimenter and either use vocalizations so that she would face them again or position themselves in front of her.

In contrast to our results, findings of E. L. MacLean et al. (2017) don't support an association between behaviour in a play test and visual attention tests. More specifically, their social referencing test, in which they measured the dogs' tendency to gaze at the experimenter when social play was interrupted, didn't load onto the same factor as a retrieval test, which assessed the tendency to return a ball to the experimenter's front (and these factors were uncorrelated). Nevertheless, as mentioned earlier, the dependent

variable of their social referencing test is more similar to the gaze duration towards the experimenter during the interruption period of our play test. Thus, we tested for associations between this variable and performance in the call and food begging tests. We didn't find any significant correlation, though it should be noted that the sample size was very small ($n = 12-13$).

4.4. ANALYSES OF THE PERSONALITY QUESTIONNAIRE

4.4.1. Factor analysis

The personality questionnaire used in this study was an abridged and translated version of the DPQ (Amanda Claire Jones, 2008), which was comprised of items that dog behaviour experts believed to be closely related to sociability/social motivation. Our initial goal was to capture a broader aspect of sociability compared to the behavioural test. While behavioural variables from the sociability test reflect a common operationalization of sociability, i.e., the tendency to approach and interact with an unfamiliar human, the purpose behind including a questionnaire was to measure sociability as a personality trait. As opposed to the behavioural test, which captures behaviour at a single point in time and in a specific context, answers on the questionnaire are expected to be based on the caregivers' observations of their dog behaviour across time and contexts.

Nevertheless, the original questionnaire is comprised of multiple factors, i.e., it measures multiple personality traits. Thus, we analysed whether the factor structure of the original questionnaire was maintained in our abridged version and our sample. We examined a 5-factor model in which Companionability was a separate factor, together with Fearfulness, Aggression towards People, Activity/Excitability and Responsiveness to Training. We found a strong positive correlation between Fearfulness and Aggression towards People, which was expected since these factors were correlated in the original questionnaire (see Table A.22). Interestingly, Companionability also showed significant negative correlations with Fearfulness and with Aggression towards People, which were strong and moderate, respectively. Companionability reflects the dog's interest in spending time with people (e.g., "Dog seeks companionship with people") and how

affectionate the dog is (e.g., “Dog is affectionate”) (Amanda Claire Jones, 2008), while Fearfulness and Aggression towards People are self-explanatory. In this case, similar to what was discussed in the Introduction chapter, Companionability could be seen as a dimension that goes from a lack of interest to positive interest toward people, i.e., a sociable-indifferent axis. In contrast, Fearfulness might represent a timid-confident axis. Nevertheless, it should be noted that the Companionability factor showed poor internal consistency (Cronbach’s alpha = .58).

4.4.2. Associations with the sociability test

Next, we examined the association of the questionnaire-derived factors with variables from the behavioural tests. Since our version of the questionnaire was built by selecting those items that were judged to be more related to sociability/social motivation by three canine behaviour experts, we plausibly had an increased probability of detecting associations. Firstly, we analysed the correlations between the factor scores and the behavioural variables of the sociability test. Dogs’ behaviours during the sociability test were associated with their score on the factors Fearfulness, Aggression towards People and Companionability (see Table 3.5). If we consider the questionnaire factor scores as valid measures of different personality traits, then this association implies that the sociability test might be influenced by and measure more than one personality trait (Carter et al., 2013; Réale et al., 2007).

Dogs that had a longer latency to establish physical contact with the experimenter during the sociability test had also higher scores on Fearfulness and Aggression towards People. This fits with the view that fearfulness can act as a suppressor in the expression of sociability (Rayment et al., 2015). Dogs with higher scores on Fearfulness spent less time in proximity and in physical contact with the experimenter during both phases of the test, while Companionability scores had a positive correlation with these variables. Dogs’ scores on Aggression towards People were negatively related to their duration of proximity and physical contact only during phase 2. This could be because an active experimenter might be more likely to elicit cautious responses from aggressive dogs than a passive one.

Generally, our results are in agreement with various studies that have shown associations between scores on fearfulness, aggression or sociability factors from questionnaires and behaviours in tests that involve an encounter with an unfamiliar human (e.g., Kutsumi et al., 2013; Mirkó et al., 2013; Svartberg, 2005). Nevertheless, the most relevant comparison might be with findings of Jakovcevic et al. (2012), who used a very similar sociability test and examined its correlations with the C-BARQ. In their study, the factor “Stranger-directed fear” was correlated with the latency to physical contact and duration of proximity during the passive phase, supporting an association between fear and behaviours in the sociability test. C-BARQ’s Stranger-directed fear and DPQ’s Fearfulness have been demonstrated to be positively correlated (Henriksson, 2016). On the other hand, Jakovcevic and collaborators didn’t find any significant correlation with C-BARQ’s Attachment/attention seeking factor, which is conceptually similar to DPQ’s Companionability and has been shown to be moderately correlated with it (Henriksson, 2016). Interestingly, in their study C-BARQ’s Trainability was related to the duration of proximity and physical contact during the passive phase, which implies a connection between dogs’ ability to attend and obey commands and their sociability. In contrast, we didn’t find any significant correlation between variables from the sociability test and the factor Responsiveness to Training. It is important to note that there were slight methodological differences between the sociability tests, such as the caregiver being present (as compared to absent), a shorter test duration (1 minute versus 2 minutes per phase) and the experimenter kneeling during the active phase (versus standing) in our study.

4.4.3. Associations with the social motivation tests

Additionally, we explored the correlations between the questionnaire factors and social motivation tests (see Table 3.6). Dogs that were rated as more fearful in the questionnaire spent less time in proximity to the experimenter in average during the play test. This association makes sense, and in our test battery implies that even during the second session, when the dogs already had a number of experiences with the experimenter, fear might have still played a role in their behaviour.

Dogs that had higher scores on Activity/Excitability approached the social toy first less often but spent more time in proximity to the experimenter in average during the play test. Given that half of the items of the factor Activity/Excitability belonged to the Playfulness facet, an association between scores on this factor and variables from the play test are expectable. Surprisingly, the correlation with the number of trials the subject approached the social toy first was negative, and there was no significant correlation with the average proportion of social play.

Scores on the Activity/Excitability factor were also correlated with variables from the conformity test. Dogs that were rated as more active/excitable chose the large amount of food in a higher proportion of trials in the test phase (i.e., when the experimenter showed a preference for the small amount) and had a lower change-in-bias. This implies that dogs that are more active/excitable (including a playfulness aspect) are less likely to conform to humans' choices or are less susceptible to human social influence.

Dogs that scored higher on Companionability had lower relative synchronization values. This is puzzling, given that the Companionability factor reflects the dogs' tendency to seek and enjoy the companionship of people and how affectionate they are. Indeed, one of the items of this factor directly referred to the animal's tendency to follow people (item 31: "Dog follows people"). Presumably, the relative synchronization is related to the dogs' tendency to follow the caregiver, since it depended on the caregiver being in view of the subject, and the caregiver moved around the house during the test. Although it was not included in the general analyses, one variable that was coded during the synchronization test was a follow score, which reflected the degree to which the subject followed the caregiver during the test. Expectedly, the relative synchronization and the follow score were strongly positively correlated (Kendall's rank correlation, $\tau(45) = .427, p < .001$). A possible explanation is that dogs that scored higher on Companionability enjoy the company of all people, that is, they discriminate less between their caregiver and familiar humans. Dogs with high scores on Companionability might have been more satisfied with the company of the experimenter, and hence might have been more inclined to stay with her in the first room during the test. However, if that was the case, we would expect a negative correlation between follow score and Companionability, but there was no significant association. Then again, Companionability didn't show a good internal consistency. Still, not even item 31 had a significant correlation with the follow score or relative synchronization.

4.4.4. Associations with the socio-cognitive tests

Lastly, we analysed the correlations of the questionnaire factors with the performance in the socio-cognitive tests (see Table 3.7). Dogs that scored higher in Activity/Excitability had lower gaze scores in the food begging test. Lower gaze scores in the food begging test reflect a lower tendency to gaze at the experimenter's face during the back condition, which could imply a poor understanding of her visual field (but see alternative interpretations of this test above). As discussed earlier, given that this factor contained items related to playfulness and a positive association between this trait and cognitive abilities has been found previously (Fugazza et al., 2022), this result is unexpected. Moreover, even without making reference to cognitive abilities, one would expect that a more active/excitable and probably more playful individual would be more likely to move from the back of the experimenter to the front and gaze at her face. Or seen in another way, more calm individuals might have been more patient and thus stayed at the back of the experimenter perhaps waiting for her to turn around and give them food again. However, this is not what we found.

Dogs with higher scores on Companionability also had higher scores in the call test. On one hand, this might mean that these dogs had a better understanding of the caregiver's visual field. On the other hand, this association supports an alternative interpretation of the test, which is that dogs that had higher scores in the test were more motivated to interact with the caregiver.

Finally, higher scores on Responsiveness to Training were also associated with higher scores in the call test. This is interesting, since it implies that obedience might have played a role in this test. On the other hand, this association might not be surprising, since this factor included items such as "Dog is attentive to owner's actions and words" and "When off leash, dog comes immediately when called." Still, although most of the subjects answered the call of their caregiver, dogs that were rated as more responsive to training had a higher tendency to position themselves in front of the caregiver and gaze at her face in the back condition. In line with what was discussed earlier, a possibility is that when confronted with contradicting cues (i.e., body orientation indicating inattentiveness and verbal cue indicating attentiveness) dogs that are more trainable pay more attention to verbal cues. These dogs might have a better understanding that the command/cue was directed at them and that it implies a willingness to interact.

Alternatively, more trainable dogs might have learned that when responding to a call command they have to position themselves in front of the human.

4.5. CLUSTER AND PROFILE ANALYSES

One of the objectives of this study was to explore whether we could find profile types or classes based on the dogs' behaviours in sociability and social motivation tests. This could be interpreted as an estimation of the degree of contextual plasticity of the individuals (Stamps & Groothuis, 2010) or the consistency/plasticity of their personality (Fratkin et al., 2013). Indeed, relative to other individuals, an individual might show high social motivation/sociability regardless of context (low contextual plasticity), while another individual might display different levels of social motivation/sociability depending on the context (high contextual plasticity). Accordingly, cluster or profile analysis might reveal groups that differ in the consistency of their scores across different social motivation tests or across different phases of the sociability test.

Cluster analysis (CA) is a technique that seeks to group objects (in this case, individuals) that are similar to each other based on a set of selected variables (i.e., clustering variables) (Hair Jr. et al., 2019). A limitation of CA is that it assumes that there are true groups in the data, and thus always generates clusters. For this reason, it is important to ensure that the cluster solutions are validated and have practical significance. Given that CA involves a high degree of subjectivity, we decided to compare our cluster solutions with those provided by latent profile analysis (LPA), which is a model-based clustering method. The rationale was that comparison of the interpretation and composition of the clusters obtained with both methods would give us an idea of the validity of the solutions. Moreover, to obtain further evidence of the validity and practical significance of the cluster solutions we examined associations with variables which were not used as clustering variables but were conceptually related to them, as well as with demographic variables.

4.5.1. Sociability variables

The sociability test consisted of two different phases that differed in the position (i.e., sitting versus kneeling) and behaviour (i.e., passive versus active) of the experimenter. It has been shown that small changes in procedures affect the results of sociability assessments, and, importantly, this effect varies between individuals (Brown et al., 2020). Interestingly, Brown and collaborators observed different patterns among the subjects. For example, some subjects showed the same duration of proximity regardless of leash presence, others remained in proximity for longer durations when leashed, yet for others the proximity duration was higher when off leash. We were interested in examining whether we could detect relevant clusters or profiles of individuals that differed on their behaviour (specifically, in the time spent close to the experimenter) during the two phases of the sociability test.

We explored 2 and 3-cluster and profile solutions. The 3-cluster solution we obtained might be more useful than the 2-cluster solution since it allowed for a more nuanced discrimination of the subjects, given that the 2-cluster solution simply generated a Low and a High Sociability group, which behaved consistently in the two phases (i.e., low or high mean duration of proximity in both phases) (see Figure 3.3 and Table A.24). In the 3-cluster solution a third group appeared, which we named Medium Sociability, that had a high mean duration of proximity only in phase 2 (i.e., active phase) (see Figure 3.4 and Table A.25). This solution also showed validity since the 3 profiles obtained through LPA were almost identical in composition to the clusters (i.e., most subjects were classified in the same group in both solutions). In contrast, the composition of the groups of the 2-cluster and 2-profile solutions differed noticeably.

Moreover, the 3-cluster solution had significant associations with the DPQ factors Fearfulness and Aggression towards People, which went in the expected direction. Specifically, the Low Sociability cluster showed a highest median Fearfulness score than the other two clusters, and a higher median Aggression towards People than the High Sociability cluster. These results suggest that both fearfulness and aggressiveness were playing a role in the dogs' behaviour during the sociability test. A significant association also emerged with the DPQ factor Activity/Excitability, with the Low Sociability cluster having the highest median value, but only differing significantly from the Medium Sociability cluster. This was unexpected, given that this factor contains a Playfulness

facet, and sociability and playfulness are assumed to be positively correlated (e.g., Hansen Wheat et al., 2019).

The 3-profile solution, but not the 3-cluster solution, also showed a relationship with the change-in-bias variable from the conformity test, which could be interpreted as the profile solution being more informative than the cluster solution. Surprisingly, the Medium Sociability profile had a higher median than the High Sociability profile, which implies that dogs that were more sociable (i.e., remained in proximity) during the active than the passive phase of the sociability test were more influenced by the experimenter's behaviour during the conformity test than dogs that were highly sociable in both phases. We hypothesize that Medium Sociability dogs might be more sensitive to changes in the experimenter's behaviour (they adapted their behaviour to the experimenter's behaviour in both the sociability and the conformity test).

Finally, it should be noted that the 2-profile solution (but not the 2-cluster solution) did not show the unexpected association with Activity/Excitability, maintained the expected association with Fearfulness and Aggression and had an additional association with Companionability, with the High Sociability profile showing higher scores. Taken together, these results suggest the existence of 2 or 3 clusters of individuals in our data, based on the time the subjects spent near the experimenter during the two different phases of the sociability test.

4.5.2. Social motivation variables

We were also interested in exploring whether we could detect profiles of subjects based on their behaviour across social motivation tests. We could not include variables from the separation episodes, synchronization and conformity tests due to limitations in sample size when working only with complete cases (i.e., no missing values in any variable). Hence, only variables from the eye contact test, unsolvable task and play test were used. For each test we selected the most relevant variable, which were the duration of eye contact, proportion of attention towards humans and average proportion of social play, respectively. When using these three measures as clustering variables, we arrived at a 3-cluster solution which didn't seem valid (see Figures 3.7 and 3.8 and Table A.26). Indeed, there was no equivalence with the 3-profile solution obtained through LPA

(which wasn't useful, given that the profiles generated didn't differ in one of the indicator variables) (see Figure 3.10), and no association was found with variables from the sociability, social cognition and the other social motivation tests. Thus, we tried different combinations of two clustering variables.

4.5.2.1. Eye contact duration and proportion of attention

When using the gaze duration from the EC test and the proportion of attention towards humans from the UT as clustering variables, a 3-cluster solution appeared the most optimal. Considering that both variables were measures of social orienting in our study, we labelled the generated clusters Low Orienting (values below average in both variables), High Attention (values above average in both variables, with the highest mean proportion of attention) and Adaptable Orienting (highest duration of eye contact with proportion of attention below average) (see Figures 3.11 and 3.12 and Table A.27). Dogs from the Low Orienting cluster established eye contact with the experimenter and directed their attention towards humans for short durations. Dogs belonging to the High Attention cluster showed the highest mean proportion of attention towards humans in the UT but did not stand out in terms of their eye contact duration with the experimenter in the EC test. Dogs in the Adaptable Orienting cluster might have adapted their strategy based on their immediate previous experience in each test. Indeed, they gazed at the experimenter for a long time during the EC test, where the experimenter had provided food directly immediately before, while they had a low proportion of attention towards humans in the UT (not different from the Low Orienting cluster), where they had been able to obtain the food by themselves in the previous trials.

We found some evidence of validity of this cluster solution since the Low Orienting and Adaptable Orienting cluster differed significantly from each other regarding the relative synchronization, with the former having lower values. Given that dogs belonging to this cluster consistently showed low social orienting (values below average in both the duration of eye contact and the proportion of attention) it seems reasonable that they would also show low social maintaining (i.e., relative synchronization). Nevertheless, they didn't differ from dogs belonging to the High Attention cluster. In fact, what was more evident was that the Adaptable Orienting cluster

had the highest median, even if the difference with the High Attention cluster did not reach significance.

In addition, the 3 profiles obtained through LPA were equivalent in their interpretation to the clusters (see Figure 3.14), although they were noticeably different in their composition (i.e., many subjects were not assigned to the same group). Overall, based on their behaviour in the eye contact test and the unsolvable task, we found some support for the existence of 3 clusters or profiles of dogs in our data.

4.5.2.2. Proportion of attention and proportion of social play

When using the proportion of attention towards humans in the unsolvable task and the average proportion of social play in the play test as clustering variables, again the most optimal solution seemed the 3-cluster solution (see Figures 3.15 and 3.16 and Table A.28). Dogs belonging to the High Social Motivation and Low Social Motivation clusters were characterized by displaying a high and a low social motivation in both tests, respectively. The Low Orienting-High Reward cluster had a mean proportion of attention below average but mean values of proportion of social play above average. The 3-profile solution obtained through LPA was equivalent in its interpretation to the 3-cluster solution (see Figure 3.18), but the composition of the profiles differed from that of the clusters. Moreover, we didn't find an association with any variables from the sociability, social cognition and the other social motivation tests. Thus, there is limited evidence of the validity and utility of this cluster solution.

4.5.2.3. Eye contact duration and proportion of social play

When including the duration of eye contact and the proportion of social play as clustering variables, we explored 2, 3 and 4-cluster solutions (see section 3.5.2.4). Overall, however, the clusters generated didn't have any association with other variables and there was no concordance with the solutions obtained through LPA. The only solution that showed some association with other sociability/social motivation variables was the 2-profile solution. The first profile was characterized by having higher mean in the

average proportion of social play than the second profile, but a lower mean duration of eye contact (see Figure 3.23). There was a significant difference between profiles in the duration of proximity and of physical contact during phase 1 of the sociability test, with the second profile having higher values in both variables. Thus, dogs that established eye contact with the experimenter for longer durations but spent a lower proportion of time engaging in social play were more sociable during the passive phase of the sociability test. If one views the proportion of social play as an indicator of playfulness, and assumes that playfulness and sociability should be positively correlated following the DS hypothesis (e.g., Hansen Wheat et al., 2019), this finding is unexpected. In any case, there is limited evidence of the validity or utility of any of the cluster or profile solutions obtained when using duration of eye contact and proportion of social play as clustering variables.

4.6. WHY WERE THE HYPOTHESES UNSUPPORTED BY THE DATA?

In this project we set out to study potential behavioural manifestations of human-directed social motivation in the domestic dog and their possible associations with sociability and social cognition. In order to do this, we tested a sample of pet dogs at their homes with a test battery in which we measured behaviours meant to be indicators of the three study constructs (i.e., social motivation, sociability and social cognition). Overall, the data didn't lend support to our hypotheses. Regarding our first hypothesis, the study failed to find evidence of the existence of three dimensions of social motivation. In fact, we couldn't even conduct a structural analysis of the data since only a few significant correlations emerged between social motivation tests, implying that they were not measuring the same construct (see discussion below). In relation to our second hypothesis, there was limited evidence of an association between presumed social motivation measures and behaviours in a frequently used sociability test. Similarly, our data didn't provide substantial support for the existence of a link between socio-cognitive abilities and sociability, and we only found scarce evidence of a relationship with presumed social motivation variables.

There are at least three major interpretations for the lack of the correlations that we had predicted in our study: (1) there is in fact no relationship between social

motivation, sociability and social cognition, (2) there is a relationship, but our tests were not adequate measures of these constructs and (3) there is a relationship, our tests were apt to measure the constructs, but they were not appropriate to reveal this association. I will discuss the two latter interpretations first. As we will see, there are several factors, such as the reliability, validity and individual variability of the tests, that should be taken into account when interpreting correlations between variables. A factor that I will not elaborate on but that can affect the ability to detect an association is statistical power; if the magnitude of the correlations is weak, our sample size might not have been enough to uncover them. This is especially true for a few of our bivariate correlations that had sample sizes around 20-30.

4.6.1. Lack of reliability of measurements

A factor that is known to affect correlations between variables is the reliability of the measurements. Unreliable data might attenuate observed correlations, although this is not always the case (Nimon et al., 2012). Importantly, in our study we assumed that individuals would differ on how they behaved when confronted with the same test (i.e., that we would find between-individual differences), but also that there would be a certain degree of consistency or stability on how an individual behaves in a particular test (i.e., within-individual consistency/stability) (see Uher, 2011). If one has an estimation of the reliability of the test (e.g., internal consistency), the test-retest correlation can tell us something about the stability of the construct.

Inter-observer reliability is frequently evaluated in dog studies, but internal consistency and test-retest reliability assessment is less common. Our battery included some tests that have been used previously in other studies but, to our knowledge, their test-retest reliability has not been assessed. This type of reliability is usually examined in personality studies (e.g., see Turcsán et al., 2018), which are concerned with consistent individual differences, or in more applied settings, such as when evaluating the utility of test batteries for assessing dogs' suitability for a working dog program or for adoption from a shelter. Yet, most of our tests have not been used in the context of the study of dog personality or individual differences. An exception is the sociability test, for which Putrino et al. (2014) estimated the test-retest reliability by examining the same dogs on

two occasions, with a separation between tests ranging from 1 to 12 months. They found a significant correlation between the sessions in the duration of physical contact during the passive phase of the test.

In our study we verified only inter-observer reliability (see Table A.6), thus, one of the limitations of our study is that we didn't evaluate test-retest reliability, which is known to affect phenotypic correlations (Garamszegi et al., 2012; Paap & Oliver, 2016) and is fundamental to confirm that the observed individual differences are stable over time (and therefore that there is evidence of the existence of “individual behavioural phenotypes” or a stable phenotypic trait; Boogert et al., 2018; Uher, 2011).

4.6.2. Lack of construct validity

Let us briefly review how correlations and lack of correlations between behaviours can be interpreted. There are several reasons why behaviours can be correlated, including (1) they were measured using a similar experimental set-up (i.e., shared method variance), (2) they are measuring the same construct/personality trait (i.e., convergent validity) and (3) they are measuring separate constructs/traits that are related (i.e., behavioural syndrome *sensu* Burns (2008) and Carter et al. (2013); see also Garamszegi et al. (2012)). The second point might be difficult to separate from the third point, which refers to the existence of a behavioural syndrome. A behavioural syndrome can be defined as “correlations between two or more personality traits through time or across contexts” (Carter et al., 2013, p. 467, Table 1). Thus, correlation between behaviours in different tests can be taken both as evidence of an association between different personality traits (i.e., behavioural syndrome) or as proof that the tests are measuring the same trait (i.e., convergent validity) (Burns, 2008; Réale et al., 2007).

Similarly, when a lack of correlations between tests is found, several interpretations are also possible. One can conclude that tests that are not correlated are measuring different personality traits or constructs. On the other hand, if one already assumes that the tests are measuring different personality traits, a lack of correlation can also be taken as an indication that the traits are not linked in a behavioural syndrome (see Carter et al., 2013 for a discussion regarding the personality-trait-validation and the behavioural-syndrome-identification interpretations).

Some researchers have warned that care should be taken when giving the same label to behaviours that are seemingly functionally similar but that are evaluated using dissimilar methods, if the assumption that they are expressions of the same latent trait has not been verified (Carter et al., 2013; Mouchet & Dingemanse, 2021). For example, no correlation was found between laboratory- and field-based assays of exploration tendency in great tits, which would imply that they are measuring two different traits (Mouchet & Dingemanse, 2021). Applying the same label to behaviours in these two tests would then be committing the jingle fallacy (using a single label for two different traits) (Carter et al., 2013).

When studying the correlation of individuals' behaviours across contexts, other relevant concept is contextual generality (and its inverse, contextual specificity). Contextual generality refers to “the extent to which scores for behaviour expressed in one context are correlated across individuals with scores for behaviour expressed in one or more contexts, when behaviour in all of the contexts is measured at the same age and time” (Stamps & Groothuis, 2010; p. 305, Table 1). Personality requires some degree of contextual generality, i.e., consistent individual differences across contexts. Often when researchers fail to find an expected correlation between two tests, they conclude that the trait is context specific (Carter et al., 2013). For example, if one evaluates response to a novel object and to a novel environment and finds no correlation between them, one could conclude that response to novelty is context specific.

Now, let us briefly reconsider the predictions of our study. Our view was that we were measuring three separate constructs (i.e., social motivation, sociability and social cognition), each with various indicator variables from several tests. One would expect behaviours from tests that are supposedly measuring the same construct to be strongly correlated (i.e., convergent validity). In addition to this, we hypothesized that there was a relationship between the three separate constructs. Thus, we would also expect behaviours from tests that are presumably measuring different but related constructs to be correlated. Importantly, correlations between measures of different constructs should be weaker than the correlation between measures of a single construct (see also Bray et al., 2017). This could solve the problem of interpretation of correlations that we mentioned earlier (i.e., whether correlation between behaviours indicates convergent validity or a behavioural syndrome). Ideally, one could perform a factor analysis that

would group together highly correlated behaviours that are explained by a latent variable (factor), thus revealing the structure of the data.

4.6.2.1. *Were the social motivation measures valid?*

The first hypothesis proposed that the variables from the social motivation tests of our battery were indicators of social motivation, since they appeared to reflect the construct (i.e., face validity). Particularly, we searched for behaviours and tests that we considered that, at least at surface level, could represent the three categories of manifestations of social motivation defined by Chevallier et al. (2012). This involved choosing human-directed social behaviours in dogs that could be functionally analogue to the human behaviours that the authors mentioned in their proposal (see also József Topál et al., 2019). In the next paragraphs, I will discuss why I think that our chosen behavioural variables/tests have face validity as measures of social motivation, but I also consider other potential interpretations.

Social motivation can be manifested through preferential attention towards social stimuli (i.e., social orienting). Chevallier and collaborators state that deficits observed in individuals with autism spectrum disorder (ASD) include, among others, impaired orienting to social visual and auditory stimuli. For example, children with ASD look more at the background than at the characters in static social photographs, and show infrequent orienting to their name (see references in Chevallier et al., 2012). For this reason, we initially considered testing the social orienting component using two tests: a visual and an auditory task. In the visual task, subjects would be presented with social and asocial visual stimuli on a screen, and we would measure the looking times at each type of stimuli (i.e., preferential looking task). Given that the tests had to be conducted in the caregivers' homes and in most cases there was only one experimenter present, this kind of test didn't seem feasible in our study. In the auditory task, we would play recordings of a person saying the subject's name and a foil name (matched in number of syllables and stress pattern but phonetically dissimilar), and we would register the latencies to react and to recover (e.g., see Mallikarjun et al., 2019; Smit et al., 2019). However, this task didn't work well in our small pilot study (n = 5) and we decided to discard it. In addition, we entertained the idea of including an olfactory task, in which subjects would be presented

with two boxes that contained t-shirts that had either been worn by an unfamiliar human (i.e., social stimulus) or were clean (i.e., asocial stimulus), and we would measure, among others, the duration of investigation of each box. This idea was also rejected during the piloting stage. Nevertheless, I think it could be interesting to include these tests, after some modifications, in future studies of social motivation in dogs.

When discussing the social orienting component of social motivation, Chevallier and collaborators also comment that in our species attention is easily captured by human faces, and they note that an additional deficit observed in individuals with ASD is diminished eye contact. Based on this, we thought that dogs' gazing behaviour towards the human face could be an indication of the social orienting component of social motivation. Given our hypothesized association between sociability and social motivation, evidence that sociability modulates dogs' gazing at the human face (Jakovcevic et al., 2012; Putrino et al., 2014) further supported the idea that this behaviour could be reflecting an aspect of social motivation. One context which has been shown to elicit this behaviour is when dogs are presented with a problem they are unable to solve (C. M. Cavalli et al., 2018). Hence, we picked two tests that have been used previously by other researchers, in which dogs are faced with an unsolvable problem, specifically with a food item they are unable to obtain. In one test, the food was in a container that was out of reach (eye contact test), and in the other, the reward was in an apparatus that was locked (unsolvable task). It has been recognized that motivational and personality differences could affect gazing behaviour in these tests (C. M. Cavalli et al., 2018).

Importantly, however, different interpretations have been proposed for gazing behaviour in this context, particularly during difficult or unsolvable problem-solving tasks (Hirschi et al., 2022; Johnston et al., 2021; Lazzaroni, Marshall-Pescini, et al., 2020; Mendes et al., 2021). The most common interpretation is that gazing is a communicative behaviour, often regarded as help-seeking. That is, rather than indicating a tendency to orient to social stimuli it could be a measure of the tendency to communicate and/or to use a social strategy to solve a problem. In any case, we believe this would be related to the "social nature" of each individual. This relationship would also be expected if the behaviour is viewed as a consequence of social inhibition or dependency on humans for problem-solving, as has also been proposed (Udell, 2015; but see Johnston et al., 2021). Gazing behaviour towards the caregiver during an unsolvable task has also been taken as a measure of the strength of the dog-caregiver relationship, and might be related to

behaviour in a prosocial task (Sanford et al., 2018). Curiously, another interpretation claims that this “looking back behaviour” is not a social/communicative strategy but is simply the result of looking at the most salient stimulus after giving up on solving the task (Lazzaroni, Marshall-Pescini, et al., 2020; Sarah Marshall-Pescini, Rao, et al., 2017). We would then argue that with this interpretation, gazing (or looking back) behaviour would depend on the social orienting component of social motivation, which would determine how salient social stimuli (e.g., humans) are for the individual. We know of at least another study that used the unsolvable task included in our battery to measure attentional bias to social stimuli (vonHoldt et al., 2017), that is, an indication of social orienting, and other authors that explicitly considered it a measure of social motivation and communication (Bray et al., 2020a, 2020b).

Recently, Mendes et al. (2021) gathered behaviours that have been commonly assessed during the unsolvable task and proposed what each of them could be proxies of. According to the authors, gaze alternations should be taken as communicative and help-seeking behaviours. In contrast, simply looking back/gazing might tell us something about the saliency of humans or the attraction to the human face (or that the subject is gathering information). In our study, we included several variables from the unsolvable task in the correlational analysis. Significant correlations with variables from other social motivation tests emerged only with the relative latencies to gaze at the humans and to first gaze alternation, which according to Mendes and collaborators would reflect the time elapsed to give up on the task and the time elapsed to communicate, respectively. No associations were found with the proportion of attention directed at the humans, which incorporated the duration of gazing towards humans, i.e., a proxy for attraction to the human face. However, the correlation between the relative latency to gaze at humans during the unsolvable task and the duration of gazing in the eye contact test could suggest that they are measuring the same trait. If that’s the case, given the nature of the eye contact test, in which there is no problem-solving task per se, it seems more likely that they were both proxies of attraction to the human face (or gathering information) than being related to “giving up”.

Besides social orienting, an additional manifestation of social motivation is finding social interactions rewarding (i.e., social reward). In this regard, Chevallier et al. (2012) emphasize that humans exert effort to obtain social rewards, which evidences their incentive value, and mention that children with ASD are less responsive to social rewards.

For this reason, initially we considered including a reinforcer efficacy test in which we would compare the number of times the subjects would obey a command when provided with a social (i.e., petting and praise) versus an asocial reward (i.e., food) (see Brown, 2019; Feuerbacher & Wynne, 2012). However, given that we didn't want the duration of the test sessions to be excessive, we discarded it in favour of other tests. Another way in which the value of social and asocial reinforcers has been examined is through a concurrent-choice test (P. F. Cook et al., 2016; Feuerbacher & Wynne, 2014; Lazzaroni, Range, et al., 2020). Importantly, it has been shown that behaviour in a task in which the dogs could choose between food and their owner in a Y-maze was predicted by caudate activation to cues predicting food or praise (P. F. Cook et al., 2016). When designing the choice test, we thought that dogs might be more motivated to choose their caregiver over a food reward when they are in an unfamiliar environment, since the caregiver might act as a safe haven. Since we would conduct the tests at the subjects' homes, we imagined that directly presenting a choice between the caregiver and food would not reveal individual differences (i.e., all or the majority of subjects would choose food). This would be accentuated by the fact that they had been food deprived before the test session. Thus, we decided to deprive the subjects of social interaction with their caregivers introducing a separation period. A study that used a very similar method to examine the preference for the caregiver compared to food in dogs and wolves was recently published (Isernia et al., 2022; but see below for a discussion on methodological differences). Nevertheless, it is true that individual differences in choice behaviour in these tests likely depend on several variables, including sensitivity to deprivation to the caregiver or food, the quality of the dog-caregiver bond and past learning histories (Isernia et al., 2022).

Another manifestation of the social reward component of social motivation refers to the preference for collaborative over individual activities, which seems to be diminished in individuals with ASD (see references in Chevallier et al., 2012). In the comparative study of cooperation, the archetypical paradigm is the loose-string task, in which two individuals must coordinate to pull together the ends of a rope to obtain a food reward that is out of reach. Although one study with dogs incorporated a cooperative and an individual version (i.e., that could be solved by a single individual) of the apparatus, these were not presented simultaneously, i.e., subjects could not choose between them (Friederike Range, Kassis, et al., 2019). While in this study dogs and wolves recruited a human partner even in the solo (individual) condition, when they could solve the task on

their own, if the animals visited the apparatus first (hence clearly seeing that it was the individual version) they almost never recruited the human partner and instead they solved the task by themselves. However, it would be interesting to present both versions of the apparatus in the same trial, so that subjects can choose whether they prefer to solve the task individually or collaboratively (as has been done in other species, e.g., keas: Heaney et al., 2017). Given the complexity of this test regarding the need for apparatuses and training, we ruled out its inclusion in our study.

Remarkably, Chevallier et al. (2012) mention that children with ASD are less likely to re-engage an experimenter when she interrupts a game. Therefore, we thought that studying whether dogs show a preference for social play with a human over individual play and whether they try to re-engage the human partner after an interruption would be relevant for the social reward component of social motivation. Indeed, a recently published study revealed that dogs do show re-engagement behaviours when joint play is interrupted, which suggests that social play might be more rewarding than individual play for some individuals (Horschler et al., 2022). Dogs' willingness to play fetch with a human has been used as a measure of social motivation (Bray et al., 2020a, 2020b). A limitation of our study is that we only examined one type of game (i.e., tug-of-war). Indeed, some caregivers mentioned that their dog was not used to playing with that kind of toys or that they didn't usually play in that way. Interestingly, a previous study found evidence of clusters of individuals that differed in their pattern with regard to play behaviour; while some clusters showed a relatively high motivation for both tugging and a ball game, others showed a preference for one type of game and others showed a low play motivation overall (Tóth et al., 2008). In addition, we didn't adapt the size of the toy to the size of the individual.

Finally, social motivation can also be manifested through a desire to engage with others over prolonged periods of time (i.e., social maintaining) (Chevallier et al., 2012). This is reflected in so-called maintaining strategies, which are behaviours that have the function of establishing, maintaining and enhancing relationships. Among these behaviours are those that increase an individual's likeability, such as nonconscious mimicry. Importantly, it has been shown that dogs synchronize their behaviour with that of humans, and that this synchronization is linked with the degree of affiliation between the partners and modulates dogs' social preferences (Duranton et al., 2019; Duranton & Gaunet, 2018). Hence, we decided to include a synchronization test in our battery.

Nonetheless, we believed that conducting the test in a familiar environment (the dog's home) would reduce the tendency to synchronize with the caregiver. Thus, we decided to modify the test so that the caregiver would disappear from the subjects' visual field temporarily if the dog didn't follow them. However, by doing this we introduced an additional factor, which complicated the analyses: the visibility of the caregiver. I estimated the average proportion of synchronization in the study by Duranton, Bedossa, et al. (2017) (summing the average duration of dog moving in the move condition and the duration of dog still in the still condition and dividing it by the total duration of the conditions), who tested pet dogs in an enclosed unfamiliar space, and it was higher than in our study ($M = .73$ in their study vs $M = .50$ in ours).

Similarly to synchronization, conformity (or social susceptibility), which involves matching the responses of others, might be driven by social motives (e.g., the desire to please; Raghanti, 2019) and increase the individual's likeability. Dogs have been shown to conform to human's choices, even when it is counterproductive (e.g., S. Marshall-Pescini et al., 2011; Sarah Marshall-Pescini et al., 2012; Prato-Previde et al., 2008). Thus, we decided to include a conformity test in our study. Interestingly, it has been found that dogs' social susceptibility is affected by previous social stimulation and treatment with oxytocin (Kis et al., 2022).

Considering all of the above, it seems reasonable to think that behaviours from the social motivation tests of our battery could reflect the same construct or, in other words, have the same underlying motivational mechanism. Again, one would assume that behaviours that are controlled by the same motivational system should be correlated with each other. Nevertheless, the pattern of correlations we found suggests that our social motivation tests were not measuring the same construct and that these behaviours are not governed by the same motivational system. Our results are in line with those of other studies in which putative social motivation variables have failed to group together in structural analyses (Bray et al., 2017; Brown, 2019).

Brown (2019) conducted two studies with shelter dogs in which they examined the associations between tests that have been used as indicators of dogs' sociability. Similarly to us, she found high correlations of behaviours within tests but little or no correlation of behaviours between tests, and concluded that the tests were measuring different constructs. In the first study, Brown included a reinforcer efficacy and a synchronicity test. In the reinforcer efficacy test the experimenter presented her palm to

the subject and rewarded palm touches with the snout with petting and vocal praise. The dependent variable was the number of palm touches over a 2-minute period. In the synchronicity test the experimenter walked the perimeter of a fenced yard during approximately 30 seconds, while the subject was off leash. The dependent variable was the proportion of time the subject was within arm's length of the experimenter. The final sample size was of 22 shelter dogs. The correlation matrix seems to show a weak positive correlation between reinforcer efficacy and synchronicity, which might not be significant given that the researcher doesn't mention it. Although we didn't include a reinforcer efficacy test, as discussed above, this test could be an indicator of the social reward component. In our study, a measure of social reward was the number of trials the subject approached the caregiver (after having chosen the food reward) in the separation episodes. We did include a synchronization test, though it should be noted that while Brown's synchronicity test measured location synchrony (i.e., proximity), we measured activity synchrony. In any case, this possible correlation between reinforcer efficacy and synchronicity in Brown's study (2019) would fit with the correlation we found between behaviour in the separation episodes and relative synchronization.

In addition, when conducting a PCA Brown found that synchronicity didn't load onto any component, and that reinforcer efficacy grouped instead with success in a pointing task and jumping behaviour in a separation test. The researcher mentions that their synchronicity test showed a ceiling effect, which could explain why synchronicity didn't correlate with other social behaviours (see section 4.6.3). Moreover, in view of the relationship between reinforcer efficacy, the pointing test and jumping during separation she proposed that they could reflect an ability to quickly learn contingencies (social reinforcement for palm touching, food reinforcement for following a pointing gesture, and, putatively, human attention for jumping). In the PCA, Brown included all behavioural variables from the tests and since some tests had more than one variable, some components were made up of variables from only one test. Since we were not interested in the correlations of behaviours within test, and given the scarcity and small magnitude of the correlations we found between tests, we didn't conduct a structural analysis (there was no correlational structure to be explained).

In the second study, Brown added a reunion test, in which the experimenter entered the pen after a 2-minute separation period, walked to the centre and knelt down. If the subject entered the 1 square-meter area around the experimenter, they petted the

dog and praised them, only stopping if the animal left proximity. The dependent variables were latency to approach (within 1 meter), duration of proximity, orienting (body oriented towards experimenter), gazing (face oriented towards experimenter), physical contact and jumping (one or more paws on the experimenter). Behaviours during reunion after a separation period can indicate the value of social interaction with the returning individual (i.e., social reward). In this study, Brown tested a new sample of 22 shelter dogs. The results show moderate positive correlations between reinforcer efficacy and duration of proximity and of jumping during the reunion test ($r = .40$ and $.55$). This fits with the notion that both tests could be measuring social reward. Only very weak-weak positive correlations of synchronicity with reinforcer efficacy and duration of orienting during reunion are apparent in the correlation matrix, which are probably not significant. In the PCA, synchronicity and reinforcer efficacy didn't load onto any component, and behaviours during reunion grouped with variables from a separation and a sociability test in two separate components. Again, the factor analysis would thus suggest that the synchronicity, reinforcer efficacy and reunion tests are tapping into different constructs.

Bray et al. (2017) tested 119 young adult guide dogs in training (German Shepherds, Labrador Retrievers and Golden Retrievers) in a battery of 11 tests that were designed to measure aspects of temperament and problem-solving. They first examined whether the data supported their hypothesized categorization of the tests by conducting a confirmatory factor analysis (CFA) designating two latent constructs: problem-solving and temperament. Similarly to us, they hypothesized that variables that measured the same construct would correlate more strongly among themselves than with variables from a related construct (i.e., correlations within temperament variables and within problem-solving variables would be stronger than correlations between variables from different categories). The results didn't support their categorization, so they conducted an exploratory PCA, which yielded four components in which temperament and problem-solving variables were mixed. Rather than concluding that the tests were not measuring what they were expected to measure, the authors proposed that the two domains (temperament and problem-solving) interact in a complex manner and they are difficult to separate.

Importantly, Bray and collaborators included a distraction and a sustained attention test in their battery, which could be conceptualized as measures of the social orienting component of social motivation. In the distraction test, the experimenter called

the subject from the end of a hallway which was initially empty but in subsequent trials had toy and treats along the route. The task thus assessed the dogs' ability to ignore salient distractors and approach an encouraging human instead, which the authors considered an indication of the temperament trait distractibility. In the sustained attention test the experimenter asked the dog to sit and then remained passive, facing the dog. The trial ended when the subject turned away from the experimenter, with a maximum trial duration of 2 minutes. This task therefore measured the dogs' attentiveness and interest towards a human, interpreted as another temperament trait. Interestingly, the attentiveness towards the experimenter in the distraction test (indicated by the average number of toys a dog contacted, reverse coded) and in the sustained attention test (indicated by the time they spent facing the experimenter) loaded onto the same component in an exploratory PCA. However, attentiveness towards the experimenter in the distraction test had a negative loading. This is counterintuitive since we would expect a positive relationship between attentiveness towards humans in the two contexts. Moreover, this component (which the authors labelled "Quiet investigation") also included variables from an isolation test, which was taken as an indicator of temperament traits activity and anxiety, and from a novel object test, which reflected the temperament trait neophobia. It could be hypothesized that individuals that contacted more toys during the distraction task, rather than being less attentive towards the experimenter might have been more interested in establishing social play. Yet neither behaviour in the distraction test, nor in the sustained attention test grouped together with retrieval score in a ball play test, which measured the subjects' willingness to play fetch with a human (i.e., social reward). While these three tests could be regarded as indicators of social motivation, the principal components analysis doesn't support this interpretation.

It is worth mentioning that Bray and collaborators also examined repeatability (rank-order stability) and construct validity (as well as predictive validity) of their test battery. To assess repeatability, all subjects completed the test battery twice, with the separation between the testing sessions being variable (apparently ranging from less than a week to over a month). Variables from the distraction, sustained attention and retrieval tests showed significant positive intraclass correlations between test sessions, suggesting that the rank-order of individual scores on behaviours of these tests was stable. To assess construct validity, Bray et al. included the C-BARQ, a 13-item attention deficit hyperactivity disorder (ADHD) rating scale and collection of salivary cortisol before

behavioural testing. They tested models in which the outcomes were the factors from the CFA or the components from the exploratory PCA and the predictors were the dog's score on the questionnaires or their salivary cortisol concentration. The PCA component "Quiet investigation" was negatively associated with C-BARQ's Excitability. Unfortunately, correlations between particular behaviours and C-BARQ scores were not reported.

In contrast, other studies provided suggestive evidence that putative social motivation indicators might indeed be measuring the same construct (E. L. MacLean et al., 2017; Pedretti et al., 2021). Pedretti et al. (2021) examined the effects of intranasally administered oxytocin on dogs' behavioural synchrony and shared attention towards their caregivers. In the behavioural synchrony test, the caregiver first called the dog and held them, then released them and walked around the perimeter of an outdoor fenced area for 1 minute, changing direction in the middle of the area. Then, the caregiver sat down in a chair for 1.5 minutes. Next, the caregiver walked around the perimeter again, crossed the centre of the area and walked around the perimeter in the opposite direction for 1 minute. Finally, the caregiver sat in a different chair for 1.5 minutes. As can be seen, this test was similar to our synchronization test, which was also composed of four phases in which the caregiver walked and sat down alternately, and which we considered an indicator of social maintaining. The researchers measured temporal synchrony (i.e., latency to switch to the same activity), activity synchrony and location synchrony, and created a composite variable which measured the duration of synchronized activity while in proximity (i.e., location plus activity synchrony). In the shared attention test, the caregiver sat in front of the dog, that was leashed to a wall, and the experimenter placed an object at each side of the caregiver. After the experimenter left, the caregiver first alternated their gaze between the dog and one of the objects for 10 seconds, then picked it up saying "Oh this is beautiful" and manipulated it for 10 seconds, still alternating their gaze between the animal and the object. Lastly, the caregiver alternated their gaze between object and dog for another 20 seconds. After this, the dog was unleashed and was free to explore the objects. The researchers measured, among other variables, the frequencies of dogs' gaze alternations between each object and caregiver, the duration of gazing towards each object and towards the caregiver, and the object the dog approached first at the end of the test. In a sample of 23 pet dogs, Pedretti et al. (2021) found that post-administration oxytocin concentration was associated with proximity duration in the synchrony test (i.e., location synchrony) and with the duration of gazing at the caregiver during the shared attention

test. While in this study the correlations between behaviours from both tests were not examined, the fact that both behaviours were affected similarly by oxytocin administration suggests that they have similar underlying mechanisms. Indeed, the researchers interpreted these results as evidence that oxytocin can increase social motivation.

Although we also conducted a synchronization test, we were not interested in so-called location synchrony (i.e., proximity maintenance) and focused on temporal and activity synchrony instead. Pedretti et al. (2021) didn't find any association between temporal and activity synchrony and post-administration oxytocin levels but mentioned that there was high individual variability in behavioural synchrony. They proposed that individual characteristics, such as breed, or training experience could have a stronger effect on behavioural synchrony than the hormonal state and the consequent willingness to affiliate. In our study, with similar sample sizes, we did find associations between relative synchronization (i.e., activity synchrony) and other putative social motivation measures (see Table 3.1), including the relative latency to gaze alternation during the unsolvable task and the proportion of trials the subject chose the large quantity in the conformity test (both negative). It should be noted that we conducted our synchronization test indoors rather than outdoors, and that the caregiver didn't call the subject right before the start of the test. Still, the average time dogs spent performing the same activity as their caregiver was very similar in both studies ($45 \pm 20\%$ of the test time in their study versus $M = 49.6\%$ and $SD = 15.4$ in ours). Curiously, some parallels can be noted between the sustained attention test and the conformity test. Particularly, in both tests the subjects were presented with two items (objects and plates), watched a human that alternated gaze and manipulated one of the items while speaking, and the item the subject approached first was registered. It might be interesting to analyse whether individuals that have a higher tendency to explore first the object the human attended to in the shared attention test are also more likely to conform (i.e., choose the plate manipulated by the human).

E. L. MacLean et al. (2017) aimed to identify the correlational structure underlying individual differences in dogs social and cognitive behaviours using the “dog cognition test battery”, which included 25 tests designed to evaluate social and physical cognition, as well as domain-general cognitive processes. Three populations of dogs were tested: assistance dogs, explosive detection dogs and pet dogs. The battery included, among others, a social referencing test and an unsolvable task. In the social referencing

test, the experimenter played with the dog using a stuffed animal, and after 10 seconds of play interrupted the game, holding the toy against the ground. The dependent variable was the mean percentage of time the subject looked at the experimenter's face during the interruption. The unsolvable task was similar to the one included in our study, but there were some differences. Dogs had to solve four solvable trials (out of a maximum of 12) before advancing to the test phase, and in the test phase four unsolvable trials were conducted. The experimenter that handled the dog, moved to the back of the room after releasing the subject and stood facing the wall. Thus, only the experimenter that placed the reward in the container remained in the centre of the room. The dependent variable was the mean duration of gazing at the experimenter's face.

An exploratory factor analysis with a data set of 433 dogs yielded a model with 6 factors, in which, remarkably, the social referencing test and the unsolvable task loaded onto the same factor. The researchers highlighted that although the contexts were different in each test, both presented the subject with the choice between attending to an object (i.e., the toy in the social referencing test and the container in the unsolvable task) or to a human. Accordingly, these tests could be taken as indicators of the social orienting component of social motivation. We did find an association between two indicators of social orienting in our test battery: gazing duration during the eye contact test and relative latency to gaze at the human in the unsolvable task.

On the other hand, social play during the social referencing test can be regarded as a collaborative interaction, and dogs' gazing behaviour towards the experimenter during the interruption period can represent a re-engagement attempt, hence indicating the value of the social interaction (i.e., social reward). Indeed, the social referencing test resembles the play test included in our battery, which we used as a measure of social reward. We only found a weak correlation between the average duration of proximity during the play test and the relative latency to gaze at the human during the unsolvable task, which went in the opposite direction to what we expected. Although in our general analyses we didn't include the variables measured during the interruption period of the play test, we later verified that there was no association with variables from the unsolvable task. However, the sample size was quite small ($n = 11/12$). In addition, there were methodological differences between our play test and the social referencing test. Specifically, given that in the social referencing test the experimenter kept the toy, dogs' gazing behaviour towards the human's face might have been an attempt to simply recover

the toy. That is, in contrast to our play test, dogs didn't have the opportunity to continue playing individually. In any case, the fact that MacLean and collaborators found that the unsolvable task and the social referencing test loaded onto the same factor supports the notion that they might be measuring the same construct.

Overall, studies that have examined the correlations and/or factor/component structure of tests that are purportedly measuring social motivation have provided mixed findings. Nevertheless, it is important to note at this point that, in fact, failing to find correlations between behaviours that are theoretically measuring the same construct is not uncommon. Here, I will review two examples: inhibitory control and prosociality.

Several studies in dogs have revealed that individual scores on tasks that are used to measure inhibitory control are not correlated at all or only weakly (Bray et al., 2014; Brucks et al., 2017; Sarah Marshall-Pescini et al., 2015; Müller et al., 2016; Vernouillet et al., 2018; for a discussion in humans see Paap & Sawi, 2014; Tsukayama et al., 2012; for a cross-species review see Völter et al., 2018). Bray et al. (2014) offered two possible interpretations for the lack of correlation between the performance scores of the inhibitory control tasks of their study: (1) the inhibitory control mechanism differs between contexts and (2) other task demands apart from inhibitory control influence performance differently across individuals and tasks. Importantly, thus, they don't conclude that there is no evidence of an inhibitory control construct or that their tests are not measuring inhibitory control. Admittedly, in the case of inhibitory control tests, finding that solving the task is more effortful in the test condition compared to a control condition, or that exertion affects performance (Brucks et al., 2017; Olsen, 2022), can be evidence that the test is capturing inhibitory control abilities (i.e., content validity, see Völter et al., 2018). On the other hand, when examining associations with caregiver-completed impulsivity questionnaires, inhibitory control tests have not demonstrated construct validity in some studies (Brucks et al., 2017; J. Fagnani et al., 2016; Olsen, 2022).

In their first interpretation, Bray and collaborators argue that each task might involve different inhibitory control mechanisms, that is, different cognitive mechanisms that can all be grouped under the label "inhibitory control". In their second interpretation, what explains the lack of correlation between inhibitory control tests is that, apart from inhibitory control abilities, they are measuring or require additional cognitive resources that differ between tasks. Sarah Marshall-Pescini et al. (2015) favoured this latter interpretation when explaining the findings of their study, in which there was a lack of

correlation between performance in two inhibitory control tasks in dogs and wolves, and emphasized the difficulty of obtaining a “clean” measure of inhibitory control (see also Müller et al., 2016). Indeed, generally, a behavioural test is likely to be influenced, and thus measure, more than one trait (Carter et al., 2013; Réale et al., 2007; Völter et al., 2018).

Müller et al. (2016) also state that weak correlations in performance in different inhibition tasks might imply that they are measuring different aspects of inhibitory control, remarking that it is a “polymorphic phenomenon” (p. 13). Brucks et al. (2017) claimed that “A first step in understanding inhibitory control within a given species is to test whether a categorization into motor inhibition, cognitive inhibition and self-control is universally applicable, and secondly to validate that the different inhibition tests indeed capture these specific aspects of inhibition” (p. 3). Thus, they used multiple tests which aimed to assess different aspects of inhibition (i.e., motor inhibition, cognitive inhibition and self-control) within individuals. This approach is remarkably similar to the one we had in our study. The researchers failed to find any significant correlations between the main variables of each test, even in the case of tests that were a priori considered part of the same category (i.e., that were purportedly measuring the same aspect of inhibitory control). Subsequently they assessed the underlying structure of their test battery through a PCA of components derived from each test, which yielded three components that didn’t match the three theoretical categories. Again, they proposed that inhibitory control is context/domain specific, rather than being a unitary process.

Vernouillet et al. (2018) focused on examining correlations between tests of motoric self-regulation exclusively. They found that the number of trials a dog needed to be successful for the first time in each test was not correlated and they were unable to use a PCA approach due to the low correlation between the different variables of the tests. The researchers highlighted that even though one common explanation for the lack of correlations among measures of inhibitory control is that it is context-dependent, even when minimizing contextual differences in their study they still didn’t find correlations between tasks. Therefore, they considered that their findings could be better explained by differences in the requirements of each test (i.e., task demands). Additionally, they mention that even categorizations of tests that seem simple can be problematic.

Recently, Olsen (2022) failed to find correlations between two tests of motor self-regulation too, even after addressing potential ceiling effects in one of the tests (see

below). Like other authors, she proposed that the tasks might be measuring different aspects of motor self-regulation, but also considered the possibility that the different tasks might measure a similar process but such a process accounts for little variance in performance across the tasks (not detectable with small sample sizes). Importantly, Olsen made an attempt to evaluate the validity and reliability of both tests and found that the reliability of one of the tasks was poor, therefore having limited capability to capture individual differences.

Another example is the construct prosociality, which refers to behaviours that are intended to benefit others. Frequently, different measures of early prosociality in humans are found to be uncorrelated (for reviews see Dunfield, 2014; Dunfield & Kuhlmeier, 2013; Paulus, 2018), and as will be evident, parallel arguments to those mentioned in the case of inhibitory control have been made. Authors have come to the conclusion that prosociality is a multidimensional construct, and have proposed different categorizations of the various behavioural manifestations of prosociality (Dunfield, 2014; Paulus, 2018; Thompson & Newton, 2013; Warneken & Tomasello, 2009a, 2009b). According to Paulus (2018), there are two main explanations for the lack of correlation between early prosocial behaviours of different categories (i.e., helping, sharing and comforting). First, even if different types of prosocial behaviours might have the same underlying motivation (i.e., seeing a negative state alleviated), prosocial tasks might differ in their socio-cognitive demands (e.g., the ability to recognize goal-directed behaviour in instrumental helping tasks versus the ability to recognize negative emotional states in comforting tasks) (Dunfield, 2014; Thompson & Newton, 2013; Warneken & Tomasello, 2009b). Alternatively, the tasks might not only differ in their socio-cognitive demands but also be driven by different motivations (Paulus, 2014). Again, we see that the conclusion is not that the different tasks are not measuring the same construct (prosociality) but that there are different categories or manifestations of the construct. Nevertheless, as with inhibitory control, control conditions can be included to verify that behaviours observed in the test condition are indicators of prosociality (i.e., validity). Moreover, there is evidence of high internal consistency in tasks from the same category (Dunfield & Kuhlmeier, 2013). Like before, it has been acknowledged that scores on prosocial tasks might reflect not only prosocial motivation but other qualities as well (Thompson & Newton, 2013).

Following the model of Chevallier et al. (2012), social motivation can be seen as a multidimensional construct. Considering the above, expecting to find an association

between purported measures of different theoretical categories (or dimensions) of social motivation was probably unrealistic. The lack of correlations between behaviours in tests categorized as belonging to different social motivation categories should not necessarily make us conclude that these tests are not measuring the same construct. On the other hand, we didn't find substantial evidence of correlation between behaviours from the same category either. This is in line with findings from studies of components of inhibitory control in dogs and of executive functions in humans (Brucks et al., 2017; Olsen, 2022; Paap & Sawi, 2014; Vernouillet et al., 2018). It should be noted that social motivation can be an imprecise construct (Keifer et al., 2019; Uljarević et al., 2019), and that even when proposing specific categories of behavioural manifestations of social motivation, the boundary between them can be fuzzy. Indeed, as evidenced throughout this thesis, on some occasions, classification of behaviours into one of the three categories of social motivation is unclear, and other alternative categorizations of the social motivation construct may well be possible (e.g., Keifer et al., 2019).

In any case, we couldn't find any factor structure in the social motivation tests of our battery due to the lack of correlation between tests. In line with what has been discussed in other topics, even if behaviours in different tests share the same motivational mechanism, they might be uncorrelated due to the different demands of each test. However, the social motivation tests from our battery do not seem particularly cognitively challenging. Still, behaviours in these tests likely depend on other factors apart from social motivation (e.g., food motivation), which might limit the possibility to find correlations across tests.

Lastly, until now we have assumed that social motivation is a construct that should show consistency across contexts. However, in line with what has been mentioned before, instead of questioning the validity of our tests, the lack of correlation between behavioural tests of social motivation could be interpreted as evidence that the trait is context-specific. Importantly, consistency across contexts is affected by the existence of individual behaviour profiles (Uher, 2011). If individuals show different behavioural response profiles or, in other words, if individuals vary in their contextual plasticity, variable-oriented correlations can't be strong. In our cluster and profile analyses we found some evidence of the existence of different profile types, some of which showed consistently high social motivation across contexts (low contextual plasticity), while others varied their expression of social motivation depending on the context (high contextual

plasticity). Nevertheless, our results in this regard should be interpreted with caution (see section 4.5).

4.6.2.2. *Were the social cognition measures valid?*

Thus far we have focused on social motivation, since studying the association between different social motivation manifestations was one of the main goals of our study. However, it is worthwhile mentioning that we also failed to find significant correlations between measures from the different social cognition tests. Again, if our social cognition tests were all measuring the same construct (i.e., social cognition) we might expect some correlation between them. This correlation would be stronger among tasks that are assumedly tapping into the same cognitive ability (i.e., between tasks measuring sensitivity to cues related to visual perspective) than among tasks measuring different abilities (i.e., between tasks assessing following of communicative signals and those assessing sensitivity to cues of visual perspective). Even if we were more conservative and didn't expect a correlation between indicators of different cognitive abilities (i.e., adopted a modular approach instead of a domain-general approach; Boogert et al., 2018), variables that aim to reflect the same ability should correlate (see also Völter et al., 2018). However, we failed to find an association even between tests that were proposed to be measuring sensitivity to cues of visual attention (i.e., the call and food begging tests).

Although there is some debate regarding the precise mechanisms that mediate success in object choice tasks (OCTs) (e.g., Bensky et al., 2013; Benz-Schwarzburg et al., 2020; Kaminski & Nitzschner, 2013), these tasks are usually considered valid for examining animals' understanding (or following) of human communicative signals. On the other hand, the tasks we used to examine understanding of (or sensitivity to cues related to) human visual field, although inspired by other studies, were relatively new and, as discussed earlier, might have some interpretation issues.

The food begging context has been used frequently when evaluating dogs' sensitivity to human's visual attention (e.g., Brubaker et al., 2019; Gácsi et al., 2004; Udell et al., 2011; for a review see Huber & Lonardo, 2023). However, in these tests the subjects are commonly presented with a choice between two humans that differ in their

attentional state. Other studies have instead worked with a single human and two conditions, in which the human is attentive or not, like we did in our study. Yet, in these studies what is taken as evidence of sensitivity to cues related to visual attention is that dogs behave differently in the two conditions, i.e., that they beg/gaze (longer) from/at the attentive human compared to the inattentive one, and they typically don't examine whether the subjects reposition themselves to be in front of the human when they have their back turned. This is the case, for example, of the study by Brubaker et al. (2019), who used a food begging test that was very similar to ours. An exception is a study by Savalli et al. (2014), in which dogs could change their position in the room depending on the owners' body orientation when communicating about the location of unreachable food (although it seems that even when they repositioned themselves dogs emitted few communicative behaviours).

Other studies that did examine whether dogs position themselves in front of the human when they have their back turned used fetching tasks (Gácsi et al., 2004; Hare et al., 1998; E. L. MacLean et al., 2017). We did consider including a ball fetching task, as has been done in other studies, but discarded it during the planning stage. Instead, we used a call test, in which, assuming the dogs understood that the caregiver was calling them to establish an interaction, if they considered the human's visual field, they would position themselves in front of the human.

To our knowledge, the same sample of dogs has rarely been tested in tasks measuring the two cognitive domains examined in our study (for an attempt at a structural analysis of dogs' intelligence see Arden & Adams, 2016). Interestingly, E. L. MacLean et al. (2014) conducted various experiments in which they examined the correlation between sensitivity to body orientation and performance in OCTs. To assess sensitivity to body orientation they used the "sit test", which consisted in four 10-second trials in which the experimenter said the dogs' name and gave the "sit" command while she was facing or had her back turned to the subject. They analysed whether the difference score from this test (percentage of trials the dog sat in the facing condition minus the percentage of trials they sat in the back condition) correlated with performance in an OCT with dynamic sustained distal pointing plus gazing. Pointing was performed with the contralateral arm from the baited container with the exception of experiment 4, in which the right arm was used in all trials. In experiment 2 the researchers found a nearly significant ($p = .05$) positive correlation, which suggested that subjects that were more

responsive to body orientation in the sit test also tended to be better at follow pointing cues in the OCT. However, in experiments 3 and 4 they didn't find a correlation between performance in these two tests. It is important to mention that while in experiment 2 the experimenter praised the dog if they sat or lay down during the trial of the sit test (regardless of condition), in experiments 3 and 4 the experimenter gave the subject a food reward at the end of each trial regardless of their behaviour. In this study the researchers also conducted different versions of the OCT to evaluate subjects' visual perspective-taking abilities in the context of point following and found that, even though dogs are skilled at following human communicative gestures and can use information about humans' visual perspective, they don't seem to integrate these skills.

Stewart et al. (2015) analysed data from a citizen science study in which caregivers carried out a series of tests with their dogs at home, which included tasks that measured following of human gestures and understanding of human visual perspective. In the arm and foot pointing tests, the caregiver stood between two pieces of food and pointed at and gazed towards one of them until the subject made their choice. In the visual perspective test, the caregiver instructed the subject not to eat a treat and then either remained facing the dog, turned their back or covered their eyes. The two types of tests didn't group together in an EFA, in which the factors were orthogonal (i.e., not correlated).

In another study, E. L. MacLean et al. (2017) used a test battery that included various conditions of the object choice task, but also a perspective-taking and a retrieval test. The perspective-taking test aimed to measure the subjects' tendency to obey a command depending on the body orientation of the experimenter (i.e., whether the experimenter was facing the dog or had their back turned). The retrieval test sought to evaluate the subjects' tendency to retrieve a ball and return it to the front of the experimenter, when in half of the trials she remained facing the dog and on the other half she turned her back. The different conditions of the OCT grouped together in one factor, while the retrieval test was assigned to the same factor as a sensory bias test. The perspective-taking test was not included in the EFA due to a low Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy.

The dependent measure of the perspective-taking test actually combined the scores of two subtests: a sit and a stay subtest. The sit subtest was similar to the one from E. L. MacLean et al. (2014), but in this case subjects received a food reward regardless

of performance and only received verbal praise if they sat or lied down. In the stay subtest, which was similar to the task presented in Stewart et al. (2015), the experimenter placed a reward in front of the dog, gave the “stay” command and then stood facing the subject or turned her back. In both subtests, higher scores reflected a greater tendency to obey the command (sit/lay down and not taking the reward) when the experimenter was facing than when she was not. It is interesting to note that in the stay subtest a second experimenter was always watching the subject, which might have affected the dogs’ behaviour.

The sit subtest is somewhat similar to the situation in the call test of our battery, but there are also some differences. For example, the call test did not necessarily include a command per se since the caregiver was free to call the subject as they would usually do, which could involve only saying the name of the dog or the name plus a command (although we would argue that only saying the name could be interpreted as a command in this context). In addition, in the call test the caregiver was not in sight of the subject when calling. Importantly, in contrast to the studies of MacLean and collaborators, in our study dogs received a higher score if they “obeyed the command” (i.e., came into the room and position themselves in front of the caregiver) in the back condition. Since in the sit subtest the subject was released when the experimenter gave the “sit” command, it would have been interesting to know whether any subject positioned themselves in front of the experimenter in the back condition before sitting. In any case, in this regard our call and food begging tests were more similar to the retrieval test of MacLean et al. (2014), in which the subjects received higher scores if they brought the ball in front of the experimenter, and so scores in this test could reflect the sensitivity to cues related to the experimenter’s visual perspective. Since the OCTs and the retrieval test were grouped into different factors and these were uncorrelated, these results are in line with the lack of correlation we found between the OCT and both the call and food begging tests. Thus, in our study, as well as in previous research (E. L. MacLean et al., 2014, 2017; Stewart et al., 2015), performance in OCTs was not associated with performance in visual perspective tasks, which could imply that following of human communicative signals is independent of the sensitivity to cues related to visual perspective of humans.

Gácsi et al. (2004) aimed to determine whether dogs showed consistent behaviour across tests that examined their ability to understand human visual attention. In their first experiment, they used three fetching tests: ball fetching, object fetching for owner sitting

on a chair, and object fetching for owner sitting on the ground, which included conditions in which the owner could be facing the dog or had their back turned and be blindfolded or not. The ball fetching test showed a floor effect, with only 2 dogs out of 17 performing above chance level, that is, most dogs didn't return the ball to the front of the owner when they had their back turned. However, apparently the authors didn't compute the correlation between the two object fetching tests.

In their second experiment, they used two food begging tests in which subjects could choose between two humans. In one of the tests the two humans were sitting on a chair facing the dog, but one was blindfolded, and thus the effect of the visibility of the eyes was examined. In the other test, both humans were sitting on opposite sides of a table, facing each other and sideways to the dog, but one turned her head towards the dog and tried to make eye contact, while the other turned her head away, so the effect of face/head orientation was inspected. In this experiment, the researchers found a positive correlation between the performance in the two tests.

Although some subjects participated in both experiments, Gácsi et al. (2004) don't report the correlation between performance in the fetching and the food begging tests. Still, they concluded that dogs' performance in tests measuring understanding of visual attention is variable and context-dependent, based on the low performance in the ball fetching task compared to the object fetching tasks, and the observation that dogs' performance was better in the food begging test that inspected the effect of head orientation than the one that examined the effect of the visibility of the eyes. However, they acknowledge that this limited capacity to show a general attention recognition ability across different contexts might be related, among other factors, to the inadequateness of experimental procedures. An important point raised by the authors is the fact that this type of tests is likely affected by habitual factors (i.e., previous experiences) and might lack ethological validity since they present situations that are not completely natural (Gácsi et al., 2004). This applies to some extent to the call and food begging tests of our battery.

4.6.3. Limited between-individual variation

Our intention was to assess the correlational structure underlying differences between individuals. However, some of the tests of our battery might not have been adequate to reveal between-individual variation (see Völter et al., 2018). Carter et al. (2013) mention two factors that might affect the degree to which inter-individual differences are evident in a test: (1) situational strength and (2) test duration. Situational strength refers to the degree to which an individual's behaviour is affected by the situation (Uher, 2011). A strong situation might restrict individuals' behaviours, "forcing" them into a specific direction, resulting in floor or ceiling effects that prevent the expression of differences between individuals. Similarly, when testing cognitive abilities, the difficulty of the test can restrict individual variability. The second factor refers to how cutting off the data after a certain time, that is, having an insufficient test duration, can also lead to ceiling or floor effects (Carter et al., 2013). The size of correlations is affected by the amount of variability in the variables, with ceiling and floor effects meaning limited variability and thus attenuation of the correlations. For example, this point has been raised when discussing the lack of correlations between inhibitory control tests in dogs (e.g., Olsen, 2022).

Some of the tests employed in our study were clearly affected by these problems, which represents a limitation in our study design. For example, the separation episodes, in which the subjects were presented with a choice between eating a food reward and greeting the caregiver, could be seen as a strong situation. The caregivers were asked whether there was a food reward that their dogs liked more than sausage, and if there was, it was used during this test; otherwise, sausage was used. This means that the food reward presented in the test was highly desirable. Not only that, but the caregivers had been asked not to feed their dog in the 4 hours before the test. Although for some separation episodes the subject had received food in previous tests of that session, the deprivation of food and of the caregiver was not comparable. The separation from the caregiver only lasted 1 minute, and during part of this period the subject was shown how the food reward was placed in their bowl. A 1-minute separation period was too short to elicit a motivation to greet the caregiver during reunion that was strong enough to surpass the food motivation in most subjects. This resulted in most individuals choosing the food, that is, a floor effect in the number of trials the caregiver was chosen. Examining dogs' choices with longer

separation periods of different durations and with food rewards of different quality (e.g., high versus low quality) could be interesting. Indeed, a recent study that used longer and equal periods of food and caregiver deprivation (at least 4 hours) found that at the group level dogs didn't show a preference, and that there were substantial individual differences (Isernia et al., 2022).

A floor effect could also be seen in the pointing condition of the OCT. In these tasks, cues can be already in place when the subject views the experimenter (i.e., static) or they can be enacted in view of the subject (i.e., dynamic). In addition, they can remain in position until the subject chooses a container (i.e., continuous/sustained) or can be presented shortly and then withdrawn (i.e., momentary). In the case of pointing, it can be proximal, when the distance from the tip of the finger to the object is smaller than 10-40 cm, and distal, when it is greater than 50 cm (see Ádam Miklósi & Soproni, 2006 for a classification of pointing cues). Importantly, performance is affected by the type of cue presented, with dynamic, sustained and proximal cues being the easiest to follow (Bensky et al., 2013). In our study we failed to take this into account, and presented a dynamic sustained proximal pointing, which most individuals successfully followed in the six trials.

Nevertheless, the variables that were more strongly skewed and/or showed the least variability, like those mentioned above, were discarded during the data pre-processing stage. Still, the distribution of some of the variables retained for the correlational analyses was not optimal and could explain the scarcity of significant correlations and their small magnitude (see Tables A.7 and A.8). For instance, in the unsolvable task, the proportion of attention towards humans was right-skewed, which might imply that a longer test duration was necessary since many subjects spent the majority of the test attending to (i.e., gazing at or interacting with) the apparatus. These results are in line with other studies that used solvable and unsolvable tasks, which found that dogs spent less or around 10% of the test gazing at the human (Brubaker et al., 2017; Lazzaroni, Marshall-Pescini, et al., 2020; Udell, 2015). Although in most studies that used the unsolvable task the duration of the unsolvable trial was of 1 minute (like in ours), which is enough to elicit communicative behaviours from dogs, this duration should be adapted to the goal of the study (C. M. Cavalli et al., 2018; Mendes et al., 2021). A longer test duration might allow the expression of more individual differences in the proportion

of attention directed towards humans during an unsolvable task (e.g., see Hirschi et al., 2022).

In the sociability test, latency to establish physical contact with the experimenter had a very low median ($Mdn = 8.6$, out of a maximum of 120 seconds). Moreover, shortening the duration of the phases of this test from 2 minutes to 1 minute each limited our ability to detect individual variation. This was especially true for the duration of proximity during the second phase (active phase), which was left-skewed, showing a ceiling effect ($Mdn = 56.2$, out of a maximum of 60 seconds).

An argument we haven't commented on is that if during domestication dogs were consistently selected for high social motivation or sociability as proposed by various hypotheses (e.g., *two behavioural tendencies hypothesis*, *emotional reactivity hypothesis*, *hypersociability hypothesis*; see section 1.1.7), this might have reduced their variability on these traits. Indeed, wolves show higher variability than dogs with regards to the time spent accepting social contact from a human (Lazzaroni, Range, et al., 2020). Yet, as we mentioned in the Introduction section, there is evidence of individual differences in sociability/social motivation in dogs. What this potentially reduced variability might mean is that we need to make a greater effort to uncover it.

4.6.4. Phenotypic and between-individual correlations

The general objective of our study was to examine correlations between behavioural traits among individuals. However, what we have analysed is whether phenotypic correlations between traits differ significantly from zero. Some authors have warned that this approach is misguided, since it assumes that phenotypic correlations match among-individual correlations, when in reality they might not be the same in sign nor magnitude (Dingemanse et al., 2012; Niemelä & Dingemanse, 2018; see also (Garamszegi et al., 2012). “Between-individual correlations can only be demonstrated by decomposing raw phenotypic correlations into between- and within-individual components” (Dingemanse et al., 2012, p. 1544). While the between-individual component represents how much individuals differ from each other in their average phenotype, the within-individual component refers to differences between repeated responses within the same individual. Thus, estimating the within-individual component

requires repeated measures of each individual. In our case, even when we had repeated measures (trials) for several behaviours, in our statistical analysis we used a method that returns unpartitioned phenotypic level correlation estimates (Niemelä & Dingemans, 2018). Therefore, in our interpretations we have been assuming that phenotypic correlations match between-individual correlations, which in turn implies making two critical assumptions: that between- and within-individual correlations are identical, and that the repeatability of the traits of interest equals 1 (Niemelä & Dingemans, 2018)

4.6.5. Lack of association between constructs

The last interpretation for the scarcity of correlations we found is that there is little or no relationship between social motivation, sociability and social cognition. This interpretation can't be properly evaluated until the issues raised in the previous sections are satisfactorily addressed. Nevertheless, let us leave aside these issues as much as possible, and ponder what the fact that we only found a few significant correlations between constructs, of small to moderate magnitude, might mean.

4.6.5.1. *Social motivation and sociability*

We have previously acknowledged that separating social motivation and sociability can lead to confusion. Indeed, sociability can be conceived as a personality trait that has particular underlying (social) motivational mechanisms. In general, one could hypothesize that the behaviours we analysed in our social motivation tests and the sociability test were all sociability-related behaviours, that is, they were measuring the same personality trait and were governed by the same motivational mechanism. If that were the case, we would have expected to find substantial correlations among tests of social motivation and sociability (i.e., convergent validity). Relatedly, one of the defining characteristics of personality traits is that individual differences in behaviour show consistency across contexts, i.e., behaviours expressed in functionally similar contexts should correlate across individuals. Instead, our results suggest that the expression of sociability-related behaviours depends on the context. Interestingly, if we maintain the

separation between sociability and social motivation, we can observe that the sociability test, which consisted of an encounter with an unfamiliar experimenter, only showed correlations with tests that measured interaction with the experimenter exclusively (i.e., the eye contact and the play tests, with the exception of the conformity test) and not with those that assessed interaction with the caregiver (i.e., separation episodes and synchronization test) or with both humans (i.e., unsolvable task). In line with this, dogs' behaviours directed towards their caregiver and towards the experimenter were separated into different components in a PCA in a previous study (A. S. Sundman et al., 2018).

It is important to remember that what we measured in the sociability test specifically was a common operationalization of sociability in dogs, i.e., the tendency to approach and interact with an unfamiliar human. Since we found little association between variables from the sociability test and social motivation indicators, we might conclude that social motivation was not driving dogs' behaviour in the encounter with the unfamiliar experimenter or that it was masked by other factors (e.g., fear). Indeed, social fear or neophobia might have a suppressive effect on behavioural responses driven by positive motivations, such as social motivation (Rayment et al., 2015). This is supported by the fact that we found significant correlations between the Fearfulness factor of our questionnaire and behaviours in the sociability test. Another possibility is that behaviours in this situation are related to the general exploratory tendency of the individual, and not necessarily linked to the social aspect of the context. In any case, our results might serve as a reminder that researchers should be cautious when assuming that behaviours in a test are governed by a particular motivational mechanism without verification. This is in part related to the "task impurity" problem mentioned earlier. Although in what follows I will refer to dogs' behaviour in the sociability test as their "sociability", the reader should bear in mind these caveats.

In the literature there is suggestive evidence in dogs of a relationship between sociability and the three social motivation components we have worked with (see section 1.5.1.3). In our study we found limited evidence of correlations between social orienting indicators and sociability. Regarding the eye contact test, it is especially noteworthy that we only partially replicated the findings of Putrino et al. (2014) despite using very similar methods, although we have highlighted earlier some methodological differences that might explain these divergent results. None of the variables from the unsolvable task correlated with behaviour in the sociability test, which could imply that the tendency to

orient towards humans or to use a social strategy in a problem-solving context is not mediated by sociability.

To our knowledge, our study is the first to directly analyse the association between dogs' sociability and their preference for the caregiver over a food reward. In the separation episodes most subjects chose the food reward first (see discussion above), but examination of behaviour after their first choice revealed more variability. Still, we didn't find an association between dogs' sociability and their tendency to approach the caregiver during reunion after having chosen the food reward. In contrast, Brown (2019) discovered correlations between behaviours in a sociability test and in a reunion test. Yet, there were substantial differences between our studies, with Brown evaluating shelter dogs' behaviour when reuniting with an experimenter in a test in which they didn't have to choose between a food reward and interaction with the human.

As far as we know, our study was also the first to analyse the relationship between dogs' sociability and their preference for social over individual play specifically. In line with other studies (Bray et al., 2017; Turcsán et al., 2018), we found some evidence of an association between behaviours in a sociability test and a play test. Although in our study we interpreted it as an indicator of the social reward component, behaviour in a play test can be a measure of the dog's willingness to play, which can be taken as an indicator of the personality trait "playfulness" (which usually only refers to social play). Indeed, some variables from our play test correlated with the Activity/Excitability factor of our questionnaire, which contained a Playfulness facet. As commented in the Introduction section, on some occasions sociability and playfulness overlap (e.g., Chapagain et al., 2020; Svartberg, 2006; Svartberg & Forkman, 2002; Turcsán et al., 2018, 2020). Moreover, increased levels of sociability and playfulness can be regarded as DS traits, and have been found to covary in both modern and ancient dog breeds (Hansen Wheat, Fitzpatrick, et al., 2019). Our results partially support these observations, and specifically suggest that more sociable individuals might be more interested in social play, at least initially, since they interacted with the social toy first in more trials but didn't show a higher proportion of social play.

We failed to find any association between social maintaining indicators and the sociability test. In the literature there is scarce evidence of a link between dogs' sociability and behavioural synchronization (Brown, 2019; Hennessy et al., 2001; Pedretti et al., 2021). In our study, dogs' sociability was not related to dog-caregiver activity synchrony,

which implies that a more sociable individual isn't more likely to synchronize their behaviour with that of others, or more specifically, with their caregiver. Indeed, the sociability and the synchronization test involved interactions with different humans: the experimenter and the caregiver. It has previously been found that dogs' behaviours directed towards their caregiver and towards an experimenter were separated into different components in a PCA (A. S. Sundman et al., 2018). Perhaps it would have been more appropriate to either measure the association between sociability and synchronization with the experimenter or to have a measure of dog-caregiver interaction and check its association with dog-caregiver synchronization. In fact, the relative synchronization was correlated with a potential measure of the dog-caregiver bond: the number of trials the subject approached the caregiver after choosing food in the separation episodes. Moreover, a study by Brown (2019) in which the synchronization and sociability tests involved the same experimenter did reveal a weak correlation across tests even with a smaller sample size than our study. It is important to notice, however, that Brown only measured location/local synchrony (i.e., proportion of time in proximity) and that shelter and not pet dogs were tested.

We believe that our study was the first to examine the association between dogs' sociability and their tendency to conform to humans' choices or their social susceptibility. It seems that even in humans the influence of personality on individual differences in conformist behaviour has received little attention, but it has been proposed that extraversion could play an important role (Hellmer et al., 2018). Two distinct motivations might underlie conformity: informational and normative (Deutsch & Gerard, 1955; but see Cialdini & Goldstein, 2004 for a review of three potential motivations in compliance and conformity). In the former, individuals conform to others' choices because they want to be correct and have little information or consider that others might be more competent or experienced in that context (informational social influence). In the latter, individuals want social approval, so even if they believe they know better, they follow others' behaviours in order to conform to group norms (normative social influence) (Hellmer et al., 2018). When searching for associations between 3.5-year-old children's conformist behaviours and their personality traits, it was found that children with higher ratings on extraversion tended to conform for normative reasons (Hellmer et al., 2018).

In our study, the proportion of trials the subjects chose the large quantity in the conformity test and the change-in-bias (difference between pre-test and test) were not

related to behaviours during the sociability test. Recently, Kis et al. (2022) found that social stimulation by the caregiver and oxytocin treatment can increase dogs' tendency to conform to the choices of an experimenter in a food choice task. Interestingly, this effect was only found when the experimenter expressed their preference for the small amount of food in a non-addressing manner (i.e., avoiding eye contact with the subject), while in our study the experimenter always addressed the subject. Therefore, it might be worthwhile checking whether an association between sociability and conformity can be found when the experimenter doesn't address the subject. Our results do not support the notion that conformity to human's choices or their social susceptibility in a food task is modulated by dogs' sociability. This could be taken as support for an alternative interpretation of dogs' behaviour in the conformity test: that it reflects obedience (see section 1.5.1.3.3). Nevertheless, we did find a correlation between a variable of this test and a social motivation measure (relative synchronization), and no correlation with the Responsiveness to Training factor. In any case, sociability and obedience might be related (e.g., Turcsán et al., 2018), though in our study Responsiveness to Training wasn't correlated to any other factor.

4.6.5.2. Social cognition and social motivation/sociability

According to the DS hypothesis, as well as the *emotional reactivity hypothesis* (and the social motivation hypothesis of Chevallier et al., 2012), there should be a positive correlation between social motivation and socio-cognitive skills. If increased social motivation and socio-cognitive abilities are part of the DS, they should covary. The *emotional reactivity hypothesis* proposes that selection for tame behaviour, which involves a reduction in fear and aggression, but also arguably an increase in social motivation, had a major role in the evolution of social cognition in dogs and perhaps in human evolution (Hare et al., 2005; Hare & Tomasello, 2005a, 2005b). Selection might release the constraints of fear, aggression and social disinterest, enabling animals to apply inherited cognitive abilities to solve new social problems. The *emotional reactivity hypothesis* implies that these socio-cognitive skills don't depend on experience with humans. Experimentally domesticated foxes have a higher social motivation and are more skilled at using human communicative gestures than control foxes, even having less experience with humans (Hare et al., 2005). On the other hand, other authors have

emphasized the role of ontogenetic experiences in dogs' interspecific socio-cognitive abilities (e.g., Udell & Wynne, 2010). Accordingly, we can expect that individuals who engage in social interactions more frequently have more opportunities to learn socio-cognitive skills, which in turn make them more capable of engaging in social interactions in a positive way, i.e., there might be a positive feedback loop between sociability and social cognition. If we combine the previous ideas, we could hypothesize that selection for tameness leads to individuals with a high social motivation that might need a lower level of human interaction to develop their socio-cognitive skills, since they take more advantage of these learning opportunities (e.g., they pay more attention to social signals). Thus, all these hypotheses would predict a positive association between sociability/social motivation and socio-cognitive abilities.

Our results only partially support these hypotheses. Indeed, we found scarce evidence of an association between performance in socio-cognitive tasks and indicators of social motivation, and no associations with behaviours in a sociability test. Although much research has been conducted to verify the *emotional reactivity hypothesis* at the species level by comparing dogs to their wild counterpart, wolves, to our knowledge little work has been done regarding the investigation of interindividual differences in dog interspecific social cognition in connection with temperament, and more specifically, with manifestations of human-oriented social motivation or sociability.

In our study, performance in the OCT didn't correlate with any behaviour in the social motivation and sociability tests. Considering the DS hypothesis, these results could be interpreted as a decoupling of the linkage between traits. Hansen Wheat et al. (2019) found that correlations across prosocial (sociability and playfulness) and reactive (fear and aggression) behaviours were only significant in the predicted negative direction in ancient breeds. They concluded that "the strength and direction of behavioural correlations in dogs are dependent on the domestication history of the dog breeds being considered (i.e., ancient vs modern breeds)" (p. 4-5). In other words, alteration of selection pressures in later stages of domestication can affect the expression of DS traits that were linked in earlier stages, resulting in a decoupling of previously correlated traits. It should be noted that the pure-bred dogs that participated in our study all belonged to modern breeds.

On the other hand, we had hypothesized that dogs with higher social motivation or sociability levels might have more learning opportunities or might take more advantage

of these opportunities. However, our results suggest that learning of human communicative gestures in pet dogs is not related to their sociability/social motivation and depends on other factors. It could be hypothesized that one such factor could be the interaction style of the caregiver. Nonetheless, Gácsi, Kara, et al. (2009) didn't find any association between dogs' success in a pointing task and the keeping condition of the dog (i.e., whether they were kept inside or outside the house), nor the duration of daily active interaction with their caregiver (i.e., whether they spent less or more than 1 hour playing, training and walking). Still, there could be an interaction between the dogs' sociability/social motivation and the interaction style of the caregiver. For example, a dog that has a high social motivation might not need a lot of social interaction for learning to follow human gestures since they are more attentive to social signals (i.e., high social motivation leads to high performance in gesture following tasks), but a dog with a low social motivation might be more or less successful depending on the amount or quality of their interactions with humans. Yet, Gácsi and collaborators also recorded how frequently the dogs initiated communication with their caregivers (which could be a measure of their social motivation) and didn't find an interaction effect with keeping conditions and duration of interaction with the caregiver when testing their effect on performance in the point-following task (but see Brubaker & Udell (2022) for evidence that pet parenting style can predict dogs' behaviour in sociability and problem-solving tests).

Our results are in agreement with findings of other researchers (Brown, 2019; Lazarowski et al., 2020; E. L. MacLean et al., 2017; A. S. Sundman et al., 2018). In a study by E. L. MacLean et al. (2017), OCTs with different gestures (pointing, gazing and reaching) loaded onto a different (uncorrelated) factor than putative social motivation tasks: a social referencing task (in which social play was interrupted) and an unsolvable task. Similarly, Sundman et al. (2018) and Lazarowski et al. (2020) failed to find correlations between behaviours in an unsolvable task and dogs' success in an OCT with momentary distal pointing and head-turning cues. These authors concluded that these tests examined different aspects of human-directed social behaviour or social cognition, that might have been selected independently.

Curiously, in the case of common-type Labradors, Sundman et al. (2018) found a negative correlation between performance in the pointing task and a component that reflected proximity to and physical contact with the owner during the unsolvable task. Negative correlations between success in a pointing test and putative social

motivation/sociability indicators also arose in a series of studies by Brown (2019) in shelter dogs. This researcher had the explicit objective of determining whether dogs' performance in OCTs is related to their sociability. In the first two studies, the experimenter used a dynamic momentary proximal pointing cue. Both studies showed a very weak-weak negative correlation with a sociability test, which consisted of an encounter with an unfamiliar human. In the second study, a weak negative correlation with a reunion test was also revealed. Meanwhile, the results regarding the association with a reinforcer efficacy test were mixed, with the first study showing a weak positive correlation and a PCA grouping together the pointing and reinforcer efficacy tests, while the second study found no correlation. In the third study a more challenging, dynamic continuous distal pointing gesture was used. In this case a weak negative correlation between the pointing and the reinforcer efficacy tests was evident. Nevertheless, when dividing dogs into a low and a high sociability group based on their behaviour in the reinforcer efficacy test, no significant difference was found between groups in their success in the pointing test (although high sociability dogs made fewer correct choices). Therefore, it seems that at least at the intraspecific level in dogs there is little support so far for the link between a more sociable temperament and a better comprehension of human communicative gestures, with some findings even suggesting a negative relationship (Brown, 2019; Gácsi, Kara, et al., 2009; Lazarowski et al., 2020; E. L. MacLean et al., 2017; A. S. Sundman et al., 2018).

Our results did show some associations between social motivation indicators and dogs' performance in tasks assessing sensitivity to cues related to visual attention. Specifically, dogs' behaviour in a play test correlated with their performance in a food begging and a call test. However, our findings were contradictory; while scores in the food begging tests were positively correlated with the social motivation variable, the score in the call test showed a negative relationship with a social motivation indicator. We discussed earlier different interpretations of these inconsistent findings and mentioned potential issues of our visual attention tasks.

In contrast to our findings, results from E. L. MacLean et al. (2017) found no association between potential social motivation indicators and a perspective-taking and a retrieval test, both of which assessed whether the subjects were sensitive to experimenter's body orientation (when obeying a command and when retrieving an object). The perspective-taking task could not be included in the factor analysis due to a

low KMO, and the retrieval task didn't load onto the same factor of any putative social motivation test. Thus, at this point it is unclear whether there is an association between social motivation/sociability and dogs' sensitivity to visual attention, and if there is, what is its direction.

4.7. LIMITATIONS AND FUTURE DIRECTIONS

Our study has various limitations that restrict the conclusions we can derive from the findings reported. Many of these limitations have been discussed in previous sections and will only be briefly recapitulated here. A set of limitations is related to the psychometric properties of the tests of our battery, particularly their reliability, validity and the individual variability that they could reveal.

Regarding reliability, the subjects participated in each test only once, so we don't have any information regarding the temporal consistency of the behaviours we measured. Our results are based on correlations between behavioural phenotypic responses, which were not decomposed in their within- and between-individual components. Some variables showed low interobserver reliability, although this was probably due to a lack of training of the second coders.

Concerning validity, the selection of the tests was based on their face validity and interpretations that other researchers have proposed for the behaviours expressed in these tests, but it is uncertain to what degree our tests were measuring what they were intended to measure. In fact, this issue was addressed to an extent in our study through assessment of the convergent validity of social motivation and social cognition tests separately. The limited number of correlations we found within social motivation and within social cognition measures could be interpreted as a lack of convergent validity, i.e., despite our expectations based on previous studies, these tests do not seem to be measuring the same construct. Another possible interpretation is that these tests were simply measuring different aspects of the same construct.

In addition to this, I acknowledged that some tests might not have been adequate to reveal between-individual variation, as evidenced by skewed distributions and possible floor and ceiling effects. Moreover, sample size might have been a limiting factor in the

case of some bivariate associations. Another limitation of our study is that we didn't address discriminant validity and instead only assessed variables that we thought should be correlated with each other.

All the aforementioned limitations affect our interpretation of the correlations across social motivation, sociability and social cognition tests. These factors preclude us from concluding that our findings provide strong evidence against our hypotheses. That is, the null findings of our study should be interpreted with all the above-mentioned caveats in mind. On the other hand, despite these limitations we managed to find some associations that should be replicated in future studies.

We believe there is still much work to be done in relation to our hypotheses, and future studies should investigate them further while addressing the limitations of our study. Social motivation and/or sociability have been hypothesized as being central to the domestication process and to human evolution. Particularly in dogs, numerous hypotheses have been put forward regarding the changes they experienced in their social behaviour and cognition during domestication, with some putting the emphasis on dogs' social motivation/sociability. Thus, a better understanding of the social motivation construct is important and will be informative for this debate.

Researchers should determine what tests can be used to measure different expressions of social motivation in dogs validly and reliably and re-examine the assumptions regarding the motivational mechanisms that might be driving behaviours in commonly used tests. In this thesis we used the conceptualization by Chevallier et al. (2012) as a basis and proposed different behaviours that could be manifestations of social motivation and tests through which they can be assessed. It is important to mention that, unbeknownst to us when designing the study, József Topál et al. (2019) had conducted a similar exercise when considering parallels between behavioural manifestations of ASD in humans and human-analogue social cognitive skills in dogs, and some similarities can be observed between their proposed measures and ours. I think it might be premature to discard the behaviours and tests included in our battery as valid measures of social motivation and have pointed out potential issues in the design of some of them that could be addressed in future studies. In addition, I have described some tests that were considered during the planning stage but were later not included in the battery, which we think could be worth studying. Apart from these, the audience effect and overimitation are two additional phenomena that could be investigated as potential behavioural

manifestations of social motivation (particularly, I view them as part of the social maintaining component of our working model). Combining behavioural studies with analysis of physiological (e.g., hormones such as oxytocin) and neurological (e.g., caudate activation) measures is also desirable.

We believe it is important to study interindividual differences in social motivation, for which it will be necessary to make sure that the tests can reveal sufficient individual variation, and check whether these individual differences are consistent across time. To the degree that these behavioural manifestations of social motivation can be understood also as manifestations of a personality trait, it is essential to not only confirm the consistency of individual differences across contexts but also across time. Thus, researchers should make the effort to collect repeated measures of the same individuals at different time points.

On the other hand, it will also be relevant to determine whether social motivation should be regarded as a context specific trait rather than expecting consistency across behavioural manifestations of social motivation in different contexts. Taking an individual-oriented approach allows to unveil individual profiles of behavioural responses across contexts and can be used to identify clusters of individuals with similar profiles. Future studies can investigate interindividual differences in contextual plasticity with regards to behavioural expressions of social motivation.

Admittedly, as I have already mentioned, separating sociability from social motivation might lead to more confusion and result in discussions regarding the use of different labels (i.e., the jingle-jangle fallacy) that might deviate the focus of attention from what is truly relevant: unveiling the associations between various human-directed social behaviours in dogs. I commented earlier on other potential approaches that we could have taken and that can be used in future research.

We think that once valid and reliable measure of social motivation in dogs have been found, the search for an association with socio-cognitive abilities might be more fruitful. As has been done with morphological and behavioural traits (Hansen Wheat et al., 2020; Hansen Wheat, Fitzpatrick, et al., 2019), more studies are needed to test the overall prediction of the DS regarding covariation of behavioural and cognitive traits in dogs. But similarly to what I have just discussed regarding individual differences in social motivation, more research needs to be conducted to investigate the existence of consistent

individual differences in socio-cognitive skills and to find the best tests to reveal them. I mentioned some shortcomings of our socio-cognitive tests that complicate their interpretation.

As a final note, although conducting the experiments at the homes of the caregivers has advantages, being more comfortable for both the subjects (they are tested in a familiar environment, which is likely less stressful) and the caregivers (they don't have to move to participate in the study, which might lead to larger sample sizes), it also has its disadvantages. Indeed, although the tests were standardized as much as possible, the characteristics of each home were different, and the experimenter had less control over the testing environment. Testing dogs in a laboratory could therefore be valuable and would enable conducting some tests that are not feasible at the caregivers' homes due to apparatus or instruments needed. An additional limitation of our study is that the unavailability of a laboratory unit to run the experimental tasks under controlled conditions and the COVID pandemics' lockdowns prevented us from conducting pilot studies and from accessing a larger sample of dog participants.

4.8. CONCLUSIONS

- 1- This study revealed no evidence of the existence of three dimensions of human-oriented social motivation in dogs, i.e., social orienting, social reward and social maintaining. The pattern of correlations across putative social motivation tests we found prevented us from conducting a factor analysis of the data.
- 2- The lack of correlations might imply that the social motivation tasks of our battery measured different traits, or that the behaviours expressed in these tests were not driven by a shared underlying motivational mechanism. Alternatively, the studied behaviours might still be valid indicators of social motivation, but the tests might have been inadequate for the study of individual differences or might not provide a clean measure, preventing us from finding existing associations. Another possibility is that, contrary to our assumptions, social motivation is not consistent across contexts, and is a context-specific trait instead.

- 3- We found limited evidence of an association between presumed behavioural manifestations of human-oriented social motivation and behaviours during a commonly used sociability test in dogs. This might imply that despite the difficulty in separating social motivation from sociability, behaviours in the social motivation tasks and in the sociability test were not driven by the same motivational mechanism. Alternately, one could hypothesize that these were all sociability-related behaviours and that our results suggest that their expression is context-specific.
- 4- Dogs' behaviours during the sociability test were associated with their score on the personality factors Fearfulness, Aggression towards People and Companionability as assessed with an abridged version of the Dog Personality Questionnaire (DPQ). If we consider the questionnaire factor scores as valid measures of different personality traits, then this association implies that the sociability test might be influenced by and measure more than one personality trait.
- 5- Factors from an abridged version of the DPQ showed several associations with behaviours in social motivation and in socio-cognitive tests. However, many of these correlations went in an unexpected direction and we struggled to find an explanation for them. It would be important to verify whether these findings can be replicated in future studies and to reflect on potential explanations.
- 6- We found suggestive evidence of the existence of clusters or profile types of individuals based on the dogs' behaviours across the phases of the sociability test and across social motivation tasks. This supports the notion that individuals might differ on the degree of consistency across contexts (i.e., their contextual plasticity), with some clusters showing a high or low relative sociability/social motivation across all contexts (i.e., low contextual plasticity), while others showed different sociability/social motivation levels depending on the context (i.e., high contextual plasticity). Still, the validity and utility of the particular cluster solutions we found seems limited.

7- We found only a small number of associations between performance in socio-cognitive tests and behaviours in social motivation and sociability tests. Our results provided little to no support for the domestication syndrome hypothesis, the *emotional reactivity hypothesis* and other hypotheses linking sociability with interspecific socio-cognitive skills in dogs. Yet, I have discussed several factors that affect the interpretation of correlations and prevent us from concluding that our findings provide unequivocal evidence against the existence of a positive link between these constructs. Hence, the null findings of our study should be interpreted with caution.

APPENDIX

Table A.1*Behavioural studies assessing sociability and related constructs in dogs*

Term (Reference)	Definition	Test Description	Measures	Sample
Sociability (1)	Variable obtained from Factor Analysis (FA)	Dog Mentality Assessment Test (DMA) subtests: <i>Social contact</i> : ST greets, takes the S for a walk and performs physical examination <i>Ghosts</i> : two STs covered in white sheets approach the S, then S is released <i>Distance play</i> : ST acts threateningly initially, hides and calls for the S, then invites the S to play	Greeting reaction, cooperation and reaction to physical examination (score 1-5) Greeting reaction when unleashed (score 1-5) Attempts to approach the ST, play tug-of-war and play invitations (score 1-5)	Pet dogs
Sociability (2)	Variable obtained from FA (Svartberg & Forkman, 2002)	DMA (earlier version) <i>social contact</i> subtest: ST greets the S and makes physical contact	Behavioural reaction (score 1-5: from avoidance with threats to intense greeting)	Pet dogs (German Shepherd and Belgian Tervuren)
Sociability (3)	Variable obtained from FA (Svartberg & Forkman, 2002)	DMA <i>social contact</i> subtest: ST greets, takes the S for a walk and performs physical examination	Greeting behaviour, following behaviour and reaction to physical handling (score 1-5)	Pet dogs
Social preferences (4)	-	Encounter with caregiver paired with other subjects/object (bottle, E, dog, conspecific pup)	Proximity (relative duration)	Dog and wolf pups
Sociability (5)	Variable obtained from FA (Svartberg & Forkman, 2002)	DMA subtests: <i>Social contact</i> : ST greets, takes the S for a walk and performs physical examination <i>Ghosts</i> : two STs covered in white sheets approach the S, then S is released <i>Distance play</i> : ST acts threateningly initially, hides and calls for the S, then invites the S to play	Greeting behaviour, following behaviour and reaction to physical handling (score 1-5) Greeting reaction when unleashed (score 1-5) Attempts to approach the ST, play tug-of-war and play invitations (score 1-5)	Pet dogs
Social impulsivity (6)	Interest in novel social companions (Fairbanks, 2001)	<i>Greeting test</i> based on DMA <i>social contact</i> subtest: ST approaches and speaks to leashed S; if S is friendly or neutral, E pats S, then steps sideways and if S follows, E pats S again, otherwise E calls S. If there is no response after call, E approaches, pats S and leaves.	Scoring system: 0-2 0 = S does not act friendly 1 = S shows friendly behaviour but does not follow E 2 = S follows E	Pet dogs (German Shepherds)
Sociability-related behavior (7)	-	Encounter with unfamiliar human (passive and active phases)	Proximity to human/door (frequency) Physical contact (frequency)	Shelter and pet dogs

Table A.1 (continued)

Term (Reference)	Definition	Test Description	Measures	Sample
Friendliness (8)	Variable obtained from Principal Component Analysis (PCA)	The Match-Up Behavior Evaluation: 19 subtests	Occurrence of 38 behaviours was scored across the subtests. The number of subtests in which each behaviour was observed was counted and summed; behaviour scores were subjected to PCA <i>Friendliness</i> : jump up, lick, play bow, high tail, wag tail, soft mouth and paw	Shelter dogs
Sociability (9)	Interest and attitude toward another member of its same species or towards humans (Svartberg, 2007)	<i>Sociability test</i> : encounter with unfamiliar human (passive and active phases)	Proximity (duration) Physical contact (latency and duration)	Pet dogs
Social responsiveness (10)	-	<i>Human interaction test</i> : encounter with unfamiliar human who ignored the S	Proximity (frequency) Physical contact (frequency) Vocalizations (frequency)	Pet dogs
Sociability (11)	Variable obtained from PCA	<i>Greeting test</i> : E crouches down and encourages the S to make contact; when approached, E pets and talks to the S	<i>Sociability</i> component: latency to approach (score), amount of tail-wagging (score), jumping up (occurrence) and pawing/rolling over (occurrence)	Border collie pups
Social bonding, social motivation (to approach and affiliate), social engagement (12)	-	Staying in experimental room for 60 minutes with O and familiar dog partner after treatment (saline/oxytocin)	Affiliation: affiliative behaviours including sniffing, licking, gentle touching and body contact (frequency) Social approach/proximity (duration and index) Social orientation (duration)	Pet dogs
Proximity seeking Friendliness (13)	Variables obtained from PCA <i>Proximity seeking</i> : how willingly the dog approaches and interacts with O and ST <i>Friendliness</i> : reaction to a threatening ST and to passive ST while facing problem box	<i>Greeting</i> subtest: a ST approaches in a friendly way while O holds the leash <i>Separation</i> subtest: O leaves the S alone, E approaches, greets and initiates play, then leaves. O returns, greets, and initiates play <i>Problem solving</i> subtest: S presented with a solvable problem in presence of E and O <i>Threatening ST</i> subtest: ST approaches threateningly while O holds the leash, then ST steps back and calls the S	Scoring system (0-3) <i>Proximity seeking</i> : - Proximity to ST (latency) in greeting, separation and threatening ST subtests - Following E and O (latency) in separation subtest - Playing with O (duration) in separation subtest <i>Friendliness</i> : - Orientation to E (frequency) during problem solving subtest - Jumping up (frequency) during threatening ST subtest - Friendly/aggressive behaviour (subjective score) during threatening ST subtest	Pet dogs (German Shepherd)

Table A.1 (continued)

Term (Reference)	Definition	Test Description	Measures	Sample
Human-directed contact seeking behaviour (also: human-directed social behaviour, social skills) (14)	Propensity to seek human contact and cooperation	Unsolvable task	Several, including: Proximity (frequency, latency, duration) Eye contact (frequency, latency, duration) Physical contact (frequency, latency, duration)	Research dogs (Beagles)
Social motivation (15)	-	Problem-solving task with 3 phases: acquisition, extinction and reacquisition	Behaviours aimed at the person (frequency) Proximity (duration) Gaze (duration)	Shelter and pet dogs
Sensitivity to /dependence on social cues (also: social response) (16)	-	Problem-solving task with/without human encouragement	Physical contact with box (latency and duration) Gaze towards human and box (duration) Success (latency)	Shelter dogs, pet dogs and wolves
Social curiosity (PC1) Social greeting (PC2) (17)	Variables obtained from PCA	DMA subtests: <i>Distance play</i> : ST acts threateningly initially, hides and calls for the S, then invites the S to play <i>Social contact</i> : ST greets, take the S for a walk and performs physical examination	<i>Social curiosity</i> : willingness to go out to the ST, play intensity and cooperation (score 1-5) <i>Social greeting</i> : greeting reaction, cooperation and reaction to physical examination (score 1-5)	Pet/working dogs (Golden and Labrador retrievers)
Sociability (18)	Tendency to approach and interact with unfamiliar people	<i>Sociability test</i> - encounter with familiar/unfamiliar human (passive and active phases)	Approach behaviour (latency) Proximity (duration)	Pet dogs and wolves
Sociability (19)	Tendency to be friendly towards STs	<i>(Sociability test)</i> - encounter with unfamiliar human (passive and active phases; including saliva sampling)	Proximity (duration) Physical contact (latency and duration)	Shelter and pet dogs
Sociability (20)	Variable obtained from FA (Svartberg & Forkman, 2002)	DMA subtests: <i>Social contact</i> : ST greets, take the S for a walk and performs physical examination <i>Ghosts</i> : two STs covered in white sheets approach the S, then S is released	Greeting behaviour, following behaviour and reaction to physical handling (score 1-5) Greeting reaction when unleashed (score 1-5)	Pet dogs
Social interest (also: inclination to seek social support) (21)	-	<i>Arena test</i> – encounter with an unfamiliar human who ignored the S, with toys present	Physical contact (duration) Approach (duration) Attention oriented (duration) Proximity (duration) Attention seeking (duration) Social exploration (duration)	Dog pups

Table A.1 (continued)

Term (Reference)	Definition	Test Description	Measures	Sample
Trust (also: attachment to humans) (22)	-	Choice between food offered from the hand directly and food placed on the ground by unfamiliar human	Proximity (latency) Physical contact (occurrence) Socialization index: tail wagging score (1-4) + gazing score (1-4)	Free-ranging dogs
Human-directed sociability	-	Solvable task <i>Sociability test:</i> encounter with familiar/unfamiliar human	Gaze (duration) Proximity (duration) Physical contact (duration)	Pet dogs and wolves
Hypersociability/exaggerated gregariousness (23)	Heightened propensity to initiate social contact Multifaceted phenotype including extended proximity seeking and gaze, heightened oxytocin levels and inhibition of independent problem-solving in the presence of humans		Calculated 3 indices: (1) attentional bias to social stimuli, (2) hypersociability, (3) social interest in STs	
Greeting/Social affiliative behaviour (24)	How the dog approaches and interacts with a friendly but unfamiliar experimenter	3 contexts: 1) first encounter with an unfamiliar E, 2) separation from the owner, 3) after E approaches in a threatening manner	Approach (score 0-3), enthusiasm (score 0-3), tail wagging (score 0-3)	Pet dogs (Border collies)
Sociability-obedience (25)	Variable obtained from PCA and EFA (factor consisting of components of different subtests): degree to which a dog is friendly towards STs, obedient and playful	Vienna Dog Personality Test (VIDOPET) subtests: <i>Greeting E:</i> E enters room where S is on leash with O, approaches, talks to them and stops in front of S <i>Greeting after separation:</i> E enters room where S is alone, waits 5 seconds for the S to approach; if S doesn't approach, calls and greets them. Then, E initiates tug-of-war play for 30 seconds. Afterwards, E leaves and O follows same procedure <i>Post-threat interaction:</i> after a threatening approach, E steps back, crouches sideways and calls the S. If S approaches, E greets the S; if not, E talks to the S for 10 seconds <i>Obedience:</i> O asks S to sit, lie down and stay, while E rustles in a box. Then O walks over to E's position and stands facing the S for 15 seconds, and calls the S <i>Ball play:</i> O throws ball three times. During first two throws, O encourages S. After third throw, O stands still and ignores S for 15 seconds. Then O leaves the ball on windowsill and walks around ignoring S	Approach (score), greeting (score) and tail wagging Component 1: approach to E (latency), approach to E (score), greeting E (score), tail wagging towards E, play intensity Approach (score), interaction (score) and tail wagging Component 1: mean latency to obey commands, mean recall latency, mean recall latency from cage Component 1: follow ball, grab ball, return, give out ball	Pet dogs (Border collies)

Table A.1 (continued)

Term (Reference)	Definition	Test Description	Measures	Sample
Sociability (26)	Variable obtained from FA (Svartberg & Forkman, 2002)	DMA subtests: <i>Social contact</i> : ST greets, take the S for a walk and performs physical <i>Ghosts</i> : two STs covered in white sheets approach the S, then S is released	Greeting behaviour, following behaviour and reaction to Greeting reaction when unleashed (score 1-5)	Pet dogs
Sociability (27)	The tendency to approach and interact with people (Svartberg, 2005)	<i>Sociability test</i> – encounter with unfamiliar human (passive and active phases)	Proximity (duration) Physical contact (duration)	Pet dogs and animal-assisted activities
Sociability (28)	Variable obtained from FA (Svartberg & Forkman, 2002)	DMA <i>social contact</i> (sociability) subtest: ST greets, takes the S for a walk and performs physical examination	Greeting reaction, cooperation and reaction to physical examination (score 1-5)	Pet dogs and wolf hybrids
Sociability (also: attraction towards humans, interest in social interaction with humans, value of human social contact) (29)		Pre-test: encounter with contact provider and food provider Test: choice between contact provider and food provider	Contact (occurrence and duration) Choice: approaching/touching Proximity (duration)	Pack-living dogs and wolves, pet dogs and free-ranging dogs
Sociability (30)	Variable obtained from EFA – <i>playfulness</i> and <i>dependency</i> components	Modified Vienna Canine Cognitive Battery subtests: <i>Greeting and playing</i> : ST and then O greet and play with S separately <i>Picture viewing</i> : O walks and stops in different locations of the room	<i>Playfulness</i> : play behaviour towards ST/O (score 0-3) <i>Dependency</i> : proximity to O (duration), follow O (duration), gaze at O (duration)	Pet dogs
Sociability-obedience (31)	Variable obtained from PCA and EFA (factor consisting of components of different subtests): degree to which a dog is friendly towards STs, obedient and playful	Vienna Dog Personality Test (VIDOPET) subtests: <i>Greeting E</i> : E enters room where S is on leash with O, approaches, talks to them and stops in front of S <i>Greeting after separation</i> : E enters room where S is alone, waits 5 seconds for the S to approach; if S doesn't approach, calls and greets them. Then, E initiates tug-of-war play for 30 seconds. Afterwards, E leaves and O follows same procedure <i>Post-threat interaction</i> : after a threatening approach, E crouches and calls S, following protocol of <i>Greeting E</i> <i>Obedience</i> : O asks S to sit, lie down and stay, while E rustles in a box. Then O walks over to a door and stands facing the S for 15 seconds, and calls the S <i>Ball play</i> : O throws ball three times. During first two throws, O encourages S. After third throw, O stands still and ignores S for 15 seconds. Then O leaves the ball on windowsill and walks around ignoring S	Subtest components: Greeting (score 0-3) Greeting (score 0-3) Greeting (score 0-3) Mean latency to obey Playfulness	Pet dogs (Border collies)

Table A.1 (continued)

Term (Reference)	Definition	Test Description	Measures	Sample
Sociability (32)	Variable obtained from FA (Svartberg & Forkman, 2002)	DMA <i>social contact</i> subtest: ST greets, takes the S for a walk and performs physical examination	Greeting behaviour, following behaviour and reaction to physical handling (score 1-5)	Pet dogs
Sociability (33)	Tendency to approach and be friendly Tendency to approach an unfamiliar human	Encounter with unfamiliar human. Obligatory vocalization phase (E uses positive vocalizations) and optional stimulus phase (E places food on the ground)	Proximity (occurrence and latency)	Free-ranging dogs
Sociability	Variable obtained from a hierarchical FA	Behaviour and Personality Assessment in Dogs (BPH) subtests: <i>Unfamiliar person</i> : assessment leader (AL) approaches S and handler, invites S to interact (phase 1); AL takes S for a short walk with interaction (phase 2); S is touched by AL (phase 3) <i>Approaching person</i> : oddly dressed person approaches slowly towards S (phase 1); S is released and free to approach person (phase 2)	Greeting and fear-related behaviours (scores) Score 0-4 in <i>unfamiliar person</i> and <i>approaching person</i> subtests	Pet dogs
People friendly (34)	Enjoys the company of unfamiliar persons, responds to invitations from STs and often invites to interactions			
Sociability with people (35)	Variable obtained from PCA	<i>Meeting a new person</i> subtest: a familiar person walked S on a leash to approach novel person; S was allowed to explore and greet the person and the novel person interacted with S if it approached	Proximity (score 1-5)	Working and breeding dogs (Anatolian shepherds)

Note. ST = stranger, S = subject, E = experimenter, O = owner. (1) Svartberg & Forkman (2002), (2) Svartberg (2002), (3) Svartberg et al. (2005), (4) Gácsi et al. (2005), (5) Svartberg (2006), (6) Hejjas et al. (2009), (7) Barrera et al. (2010), (8) Dowling-Guyer et al. (2011), (9) Jakovcevic et al. (2012), (10) Rosado et al. (2012), (11) Riemer et al. (2013), (12) Romero et al. (2014), (13) Kis et al. (2014), (14) Persson et al. (2015), (15) Barrera et al. (2015), (16) Udell (2015), (17) Sundman et al. (2016), (18) Bentosela et al. (2016), (19) Shin & Shin (2017), (20) Barnard et al. (2017), (21) Guardini et al. (2017), (22) Bhattacharjee et al. (2017), (23) vonHoldt et al. (2017), (24) Turcsán et al. (2017), (25) Turcsán et al. (2018), (26) Barnard et al. (2018), (27) Cavalli et al. (2018), (28) Wheat et al. (2018), (29) Lazzaroni et al. (2020), (30) Chapagain et al. (2020), (31) Turcsán et al. (2020), (32) Gobbo & Zupan (2020), (33) Bhattacharjee et al. (2021), (34) Svartberg (2021), (35) McConnell et al. (2022).

Table A.2

Dog personality questionnaires including factors/facets related to sociability

Name (Reference)	Description	Dimensions	Measure	Factor/Facet	Definition	Items
Canine Behavioural Assessment and Research Questionnaire (Hsu & Serpell, 2003)	132 items with behavioural descriptions - 68 items retained in FA	11 factors: Stranger-directed aggression, Owner-directed aggression, Stranger-directed fear, Non social fear, Dog-directed fear/aggression, Separation-related behaviour, Attachment or attention-seeking behaviour, Trainability, Chasing, Excitability, Pain sensitivity	5 point frequency / qualitative scale	Stranger-directed aggression (SDA)	Tendency to respond aggressively to strangers approaching or invading the dog's or owner's personal space, territory or home range	10 items, for example: <i>Dogs act aggressively when approached directly by an unfamiliar male adult while being walked or exercised on a leash</i> <i>Dogs act aggressively toward unfamiliar persons approaching the dog while it is in the owner's car</i> <i>Dogs act aggressively when strangers walk past the home while the dog is in the yard</i>
				Stranger-directed fear (SDF)	Tendency to respond fearfully when approached directly by strangers	4 items: <i>Dog acts anxious or fearful when approached directly by an unfamiliar male/female adult while away from the home (x2)</i> <i>Dog acts anxious or fearful when approached directly by an unfamiliar child while away from the home</i> <i>Dog acts anxious or fearful when unfamiliar persons visit the home</i>
				Attachment or attention-seeking behaviour	Tendency to maintain close proximity to the owner or other members of household, to solicit affection or attention, and to become agitated when the owner gives attention to third parties	6 items, for example: <i>Dog tends to sit close or in contact with a member of the household when that individual is sitting down</i> <i>Dog tends to follow a member of the household from room to room about the house</i> <i>Dog tends to nudge, nuzzle, or paw a member of the household for attention when that individual is sitting down</i>
Monash Canine Personality Questionnaire Revised (Ley, Bennett et al., 2009)	41 adjective-based items - 26 items retained in SEM	5 factors: Extraversion, Motivation, Training focus, Amicability, Neuroticism	6-point scale	Amicability	How the dog is perceived to tolerate other individuals, be they humans, dogs or other animals	3 items: <i>Gentle</i> <i>Happy-go-lucky</i> <i>Unaggressive</i>
Dog Personality Questionnaire (Jones, 2008)	75-items (long version) / 45-items (short version) with adjectives and behavioural descriptions	5 factors: Fearfulness, Aggression towards People, Activity/Excitability, Responsiveness to training, Aggression towards animals	7-point scale	Companionability (facet of Activity/Excitability)	Facet from Activity/Excitability factor. Includes items pertinent to dogs' interest in spending time with people and how affectionate the dogs are	5 items (long version) / 3 items (short version): <i>Dog seeks companionship from people</i> <i>Dog is aloof</i> <i>Dog is affectionate</i>

Table A.2 (continued)

Name (Reference)	Description	Dimensions	Measure	Factor/Facet	Definition	Items
Personality Questionnaire (Kubinyi et al., 2009)	24 items with adjectives and behavioural descriptions (derived from Human Personality Inventory) - 17 items retained in FA	4 factors: Calmness, Trainability, Dog sociability, Boldness	Score 0-2	Boldness	-	3 items: <i>Is rather cool, reserved</i> <i>Is unassertive, aloof when unfamiliar persons enter the home</i> <i>Is sometimes fearful, awkward</i>
Dog Personality Questionnaire (Mirkó et al., 2012)	38 adjective-based items (with concise examples) - 21 items retained	4 factors: Stranger-directed sociability, Activity, Aggressiveness, Trainability	5-point Likert scale	Stranger-directed sociability	-	4 items: <i>Brave</i> : does not get frightened easily by different objects, animals or humans, is confident even in new environments <i>Mistrustful (-)</i> : remains out of touch and is evidently tenseful when an unfamiliar human is approaching <i>Initiative</i> : initiates contact with unfamiliar humans, when he/she fails to make the owner tender him/her, tries to do the same with a nearby unfamiliar human <i>Afraid of noises (-)</i> : gets frightened or restless of loud sounds like thunderstorm, gunshot, etc.
Dog personality and unwanted behaviour questionnaire (Salonen et al., 2021)	63 adjective-based items (with definitions)	7 factors: Insecurity, Training focus, Energy, Aggressiveness/Dominance, Human sociability, Dog sociability, Perverserance	5-point scale (plus "I don't know")	Human sociability	The dog's tendency to social behavior with people	8 items, for example: <i>Affectionate with people</i> : seeks physical closeness with people. For example, sleeps or relaxes next to people or on their lap, begs petting <i>Sociable with people</i> : appears to like the company of people. Seeks company of people and wants to spend time with them <i>Human-oriented</i> : enjoys the company of people more than the company of other dogs

Table A.3

Evidence of validity and reliability of dog personality questionnaires including factors/facets related to sociability

Name (Reference)	Factor/Facet	Validity	Reliability	Sample
Canine Behavioural Assessment and Research Questionnaire (Hsu & Serpell, 2003)	Stranger-directed aggression (SDA)	Convergent & discriminant validity (Hsu & Serpell, 2003) - expected correlations with particular behavioural problems	Internal consistency (Hsu & Serpell, 2003; Svartberg, 2005)	Pet dogs
	Stranger-directed fear (SDF)	Convergent & discriminant validity (SDA & SDF) (Svartberg, 2005) - correlation with sociability factor from DMA	Inter-rater reliability (Ondrašovičová et al., 2013)	
	Attachment or attention-seeking behaviour	<i>Convergent</i> validity (SDF) (De Meester et al., 2008) - correlation with posture score in Socially Acceptable Behaviour subtests involving an unfamiliar human <i>Convergent validity</i> (SDF) (Kutsumi et al., 2013) - correlation with "positive response to stranger" factor derived from handling and command subtests		
Monash Canine Personality Questionnaire Revised (Ley, Bennett et al., 2009)	Amicability	Construct validity (Ley, Bennett et al., 2009)	Internal reliability (<i>consistency</i>) (Ley et al., 2009)	Pet dogs
		<i>Convergent</i> validity (Ottenheimer Carrier et al., 2013) - correlation with play behaviour towards conspecifics in a dog park	Inter-rater reliability (Ley, McGreevy, et al., 2009; Posluns et al., 2017) Test-retest reliability (Ley, McGreevy, et al., 2009) - 6 months	
Dog Personality Questionnaire (Jones, 2008)	Companionability (facet of Activity/Excitability)	Content validity (Jones, 2008)	Internal consistency (Jones, 2008)	Pet dogs
		Construct validity (Jones, 2008)	Inter-rater reliability (Jones, 2008)	
		Predictive validity (Jones, 2008) - correlations with behavioural ratings (e.g., interested in people, affectionate) in subtests involving, among others, a threatening/friendly approach, petting from a stranger or engagement in play	Test-retest reliability (Jones, 2008) - 1-2 months	
Personality Questionnaire (Kubinyi et al., 2009)	Boldness	-	Test-retest reliability (Kubinyi et al., 2009) - 1 day	Pet dogs
Dog Personality Questionnaire (Mirkó et al., 2012)	Stranger-directed sociability	Discriminant validity (Mirkó et al., 2012)	Internal consistency (Mirkó et al., 2012)	Pet dogs
		External validity (Mirkó et al., 2012) - positive correlation with amount of daily owner-dog interaction		
		<i>Convergent validity</i> (Mirkó et al., 2013) - correlations with behaviour in greeting test with unfamiliar human and play behaviour with experimenter		

Table A.3 (continued)

Name (Reference)	Factor/Facet	Validity	Reliability	Sample
Dog personality and unwanted behaviour questionnaire (Salonen et al., 2021)	Human sociability	Convergent (concurrent) validity (Salonen et al., 2021) - hypothesized correlations with training focus and insecurity	Inter-rater reliability (Salonen et al., 2021)	Pet dogs
		Discriminant validity (Salonen et al., 2021)	Test-retest reliability (Salonen et al., 2021) - mean of 58 days	
		<i>Predictive validity</i> (Salonen et al., 2022) - significant predictor of outcome variable "fear-aggression"		

Note. In the validity and reliability columns, italics means that the type of validity/reliability was not explicitly mentioned by the authors of the study. For the rest, the name of the type of validity/reliability is the one provided by the authors.

Table A.4

Correlation between factors/facets of dog personality questionnaires including sociability-related factor/facets

Questionnaire	Sociability-related factor/facet	C-BARQ	MCPQ-R	DPQ
Canine Behavioural Assessment and Research Questionnaire (C-BARQ) (Hsu & Serpell, 2003)	Attachment-attention seeking		-	Moderate positive correlation with <i>Companionability</i> (Henriksson, 2016)
	Stranger-directed aggression		Strong negative correlation with <i>Amicability</i> (Henriksson, 2016)	Moderate-strong positive correlation with <i>Fear of people (facet) & Aggression towards people</i> (Henriksson, 2016)
				Weak negative correlation with <i>Companionability</i> (Henriksson, 2016)
	Stranger-directed fear		Strong positive correlation with <i>Neuroticism</i> (Henriksson, 2016)	Moderate-strong positive correlation with <i>Fear of dogs (facet), Fear of people (facet), Non-social fear (facet) & General aggression (facet)</i> (Henriksson, 2016)
		Moderate negative correlation with <i>Amicability</i> (Henriksson, 2016)	Weak negative correlation with <i>Companionability</i> (Henriksson, 2016)	
Monash Canine Personality Questionnaire Revised (MCPQ-R) (Ley et al., 2009)	Amicability	Moderate negative correlation with <i>Stranger-directed fear, Stranger-directed aggression, Dog-directed fear & Dog-directed aggression</i> (Rayment et al., 2016)		Moderate-strong negative correlation with <i>Aggression towards animals, Aggression towards people & Fearfulness</i> (Posluns et al., 2017)
		Moderate-strong negative correlation with <i>Stranger-directed fear, Stranger-directed aggression, Dog-directed fear & Dog-directed aggression</i> (Henriksson, 2016)		Moderate-strong negative correlation with <i>Aggression towards people, Aggression towards animals, Fear of dogs (facet), Fear of people (facet) & Non-social fear (facet)</i> (Henriksson, 2016)
				Moderate positive correlation with <i>Companionability</i> (Henriksson, 2016)
Dog Personality Questionnaire (DPQ) (Jones, 2008)	Companionability	Weak negative with <i>Stranger-directed fear & Stranger-directed aggression</i> (Henriksson, 2016)	Moderate positive correlation with <i>Training focus & Amicability</i> (Henriksson, 2016)	
		Moderate positive correlation with <i>Attachment-attention seeking</i> (Henriksson, 2016)		

Note. On the second column the sociability-related (human-directed) factors or facets of each questionnaire are presented. Reading by rows, the correlations of each of this factors/facets with other questionnaire's factors/facets can be found. Correlation interpretation: $|r| < .3$ = weak, $.3 \leq |r| \leq .5$ = moderate, $|r| > .5$ = strong. In the case of Henriksson (2016), only the strongest/most relevant correlations are presented here; see paper for other significant correlations.

Table A.5*Variables coded in each behavioural test*

Test description (number of trials)	Variable	Variable description	Variable type
Eye contact: E gazes at S, after having delivered food from a visible but unreachable container during the previous minute.	Latency to first gaze	Time elapsed from the start of the test until S establishes eye contact with E	Quantitative continuous
	Duration of gaze	Time during which S establishes eye contact with E	Quantitative continuous
Unsolvable task: S is presented with an apparatus that contains a food reward that is unobtainable, after 3 repetitions in which S was able obtain the reward.	Latency to gaze apparatus / human	Time elapsed from the start of the trial until, from a stationary position, S gazes at apparatus / a human (E or C)	Quantitative continuous
	Latency to interact with apparatus / human	Time elapsed from the start of the trial until S directs a behaviour towards the apparatus (e.g., lick, sniff, scratch) / establishes physical contact with a human (E or C)	Quantitative continuous
	Duration of gaze towards apparatus / humans	Time during which, from a stationary position, S gazes at the apparatus / a human (E or C)	Quantitative continuous
	Duration of interaction with apparatus / humans	Time during which S directs a behaviour towards the apparatus (e.g., lick, sniff, scratch) / establishes physical contact with a human (E or C)	Quantitative continuous
	Frequency of gaze alternation	Number of times S alternates gaze (gaze at human's face followed by gaze at apparatus or viceversa, within a 2-second range)	Quantitative continuous

Table A.5 (continued)

Test description (number of trials)	Variable	Variable description	Variable type
Unsolvable task: S is presented with an apparatus that contains a food reward that is unobtainable, after 3 repetitions in which S was able obtain the reward	Latency to gaze alternation	Time elapsed from the start of the trial until S alternates gaze (gaze at human’s face followed by gaze at apparatus or viceversa, within a 2-second range)	Quantitative continuous
	Duration of other behaviours	Time during which S performs other behaviours not included in the other categories (e.g., locomotion)	Quantitative continuous
Separation episodes (4): C leaves the house for 1 minute. At the end of the minute, S can choose between greeting C or going to a container with their favourite food reward.	First choice	Option S approaches first	Qualitative binary (food/owner)
	Approaches non-chosen option	Whether S approaches the option not chosen in their first choice	Qualitative binary (1/0)
Play (4): two identical toys are presented, and E kneels behind one of them. The duration of the trial is 1 minute, during which S can choose with toy to interact with. If at the end of the minute S is playing with E, she stops playing and remains passive during 1 additional minute (interruption period).	First toy approached	First toy S approaches at 0.5 meters approximately	Qualitative binary (social/individual)
	First toy touched	First toy S touches	Qualitative binary (social/individual)
	Duration of proximity to E	Time during which S is in proximity to E (within arm’s reach)	Quantitative continuous

Table A.5 (continued)

Test description (number of trials)	Variable	Variable description	Variable type
<p>Play (4): two identical toys are presented, and E kneels behind one of them. The duration of the trial is 1 minute, during which S can choose with toy to interact with. If at the end of the minute S is playing with E, she stops playing and remains passive during 1 additional minute (interruption period).</p>	Duration of interaction with “social” / “individual” toy	Time during which the S interacts with the toy in front of E (“social”) / the “individual” toy (includes sniffing, following toy’s movement with their head; doesn’t include physical contact without active interaction -e.g., lying on toy-)	Quantitative continuous
	Frequency of re-engagement behaviours (interruption period)	Number of behaviours S performs to get E to play again (includes gazing at E, vocalizing, establishing physical contact, giving toy)	Quantitative discrete
	Time visible	Time during which S is visible or it can be known whether S is playing and with which toy	Quantitative continuous
	Duration of gazing at E (interruption period)	Time during which, without interacting with any toy and being stationary, S gazes at E	Quantitative continuous
	Frequency of gaze alternation (interruption period)	Number of times in which S alternates gaze (gaze at human’s face followed by gaze at a toy or viceversa, within a 2-second range)	Quantitative discrete
	Duration of individual play (interruption period)	Time during which S interacts with a toy	Quantitative continuous
	Latency to stop playing (interruption period)	Time elapsed from the start of the interruption period (E releases toy) until the end of S’ last interaction with a toy	Quantitative continuous
	Duration of proximity to E (interruption period)	Time during which S is in proximity to E (within arm’s reach)	Quantitative continuous

Table A.5 (continued)

Test description (number of trials)	Variable	Variable description	Variable type
<p>Conformity (variable): S must choose between two plates with different amounts of food. Initially a pre-test of 4-6 trials is carried out. Afterwards, the test takes place (6 trials), in which two plates are presented again and E shows interest for the one with the smaller amount.</p>	Large chosen (pre-test / test)	Whether S chose the larger amount (in the pre-test and test)	Qualitative binary (1/0)
	Chosen side	Side of the plate chosen by S	Qualitative binary (R/L)
	Looks at both plates	Whether S looks at both plates before choosing	Qualitative binary (1/0)
	Closer side	Side of the plate closer to S	Qualitative nominal (R/L/none)
<p>Synchronization: C follows a path previously indicated by E, in which she walks and stops at different locations of the house. The test lasts 1 minute (4 phases).</p>	Duration of synchronized movement / stationary	Time during which S and C are in movement / stationary simultaneously (only when C is visible to S)	Quantitative continuous
	Latency to follow C	Time elapsed since C stops being visible to S until S starts moving in the same direction C went (phase 1). If S doesn't follow C, maximum latency is coded (since C stops being visible until the end of the test)	Quantitative continuous
	Latency to switch to same activity	Time elapsed since C starts moving (phases 1 and 3) / being stationary (phases 2 and 4) until S does the same (only when C is visible to S). If S doesn't switch activity, maximum latency is coded (duration of the phase)	Quantitative continuous

Table A.5 (continued)

Test description (number of trials)	Variable	Variable description	Variable type
<p>Synchronization: C follows a path previously indicated by E, in which she walks and stops at different locations of the house. The test lasts 1 minute (4 phases).</p>	Duration of movement / stationary C	Total time during which C is moving / stationary (only when C is visible to S)	Quantitative continuous
	Phase duration	Exact duration of each phase	Quantitative continuous
	Score	0 = S doesn't follow C to the second room 1 = S follows C to the second room, but not back to the first room 2 = S follows C through the whole test	Qualitative ordinal
<p>Sociability: C and S enter a room in which E, a stranger to the animal, is sitting. The procedure consists of two phases of 1 minute each. In the first phase, E remains passive, petting S if they establish physical contact. In the second phase, E calls S and interacts with them if they approach.</p>	Latency to proximity to E	Time elapsed from the start of the test (C releases S) until S is in proximity to E (S has at least one body part, except the tail, inside or over the semi-circumference)	Quantitative continuous
	Latency to physical contact with E	Time elapsed from the start of the test (C releases S) until S establishes physical contact with E	Quantitative continuous
	Duration of proximity to E (phase 1 / 2)	Time during which S is in proximity to E (S has at least one body part, except the tail, inside or over the semi-circumference)	Quantitative continuous
	Duration of physical contact with E (phase 1 / 2)	Time during which S is in physical contact with E	Quantitative continuous

Table A.5 (continued)

Test description (number of trials)	Variable	Variable description	Variable type
Object choice – pointing (6) / gazing (6): S must choose between two cups, with one of them baited. E points with her finger / gazes at the cup under which the food is hidden.	Success	Whether S chooses the cup pointed / gazed at by E	Qualitative binary (1/0)
	Call (6): C calls S, who is with E in another room. In each trial, C is either facing towards or with their back turned towards the door of the room through which S would enter.	Answers the call	Whether S comes when called (enters the room or area where C is)
	Number of calls needed	Number of times C calls until S answers the call	Quantitative discrete
	Gazes at C	Whether S gazes at C's face	Qualitative binary (1/0)
	Duration of gaze at C	Time during which S gazes at C's face	Quantitative continuous
	Time visible	Time during which S is visible or it can be known whether they are gazing at C	Quantitative continuous
	Enters the room	Whether S walks inside the room (1) or stays at the door (0)	Qualitative binary (1/0)
	Stays in the room	Whether S stays in the room / door during the whole trial	Qualitative binary (1/0)

Table A.5 (continued)

Test description (number of trials)	Variable	Variable description	Variable type
Call (6): C calls S, who is with E in another room. In each trial, C is either facing towards or with their back turned towards the door of the room through which S would enter.	Proximity to C	Whether S stands, sits or lies in front of or next to C, in close proximity, during most of the trial	Qualitative binary (1/0)
Food begging (6): E initially gives food to S from a container on a stool. Afterwards, in each trial, E stops giving food and E or the stool change their orientation in respect to S.	Success	Whether S stays in front of E during the whole trial (“facing” trials) / goes in front of E during the trial (“back” trials)	Qualitative binary (1/0)
	Gazes	Whether S gazes at E’s face	Qualitative binary (1/0)
	Vocalizes	Whether S vocalizes	Qualitative binary (1/0)

Note. E = experimenter, S = subject, C = caregiver

Table A.6

Interobserver reliability

Test	Variable	Estimate (95% CI)	Coefficient
Eye contact	Latency to first gaze	.99 (.96 – .99)	ICC
	Duration of gaze	.99 (.98 – 1.00)	ICC

Table A.6 (continued)

Test	Variable	Estimate (95% CI)	Coefficient
Unsolvable task	Latency to gaze human	.53 (.05 – .81)	ICC
	Duration of gaze towards apparatus	.99 (.97 – 1.00)	ICC
	Duration of gaze towards humans	.98 (.94 – 1.00)	ICC
	Duration of interaction with apparatus	.98 (.53 – 1.00)	ICC
	Frequency of gaze alternation	.64 (.26 – .86)	ICC
	Latency to gaze alternation	.65 (.25 – .86)	ICC
Separation episodes	First choice	.83	Kappa
	Approaches owner after choosing food	.87	Kappa
Play	First toy approached	.92	Kappa
	First toy touched	.46	Kappa
	First toy interacted with	.69	Kappa
	Duration of proximity to E	.99 (.97 – .99)	ICC
	Duration of interaction with “social” toy	.95 (.86 – .98)	ICC
	Duration of interaction with “individual” toy	.91 (.86 – .94)	ICC
	Time visible	.99 (.99 – 1.00)	ICC
	Frequency of re-engagement behaviours (interruption period)	.90 (.80 – .95)	ICC
	Duration of gazing at E (interruption period)	.95 (.90 – .98)	ICC
	Frequency of gaze alternation (interruption period)	.52 (.20 – .73)	ICC
	Duration of individual play (interruption period)	.99 (.99 – 1.00)	ICC
	Latency to stop playing (interruption period)	.99 (.99 – 1.00)	ICC

Table A.6 (continued)

Test	Variable	Estimate (95% CI)	Coefficient
Play	Duration of proximity to E (interruption period)	.67 (.37 – .84)	ICC
Synchronization	Duration of synchronized movement	.99 (.97 – 1.00)	ICC
	Duration of synchronized stationary	.90 (.79 – .96)	ICC
	C Visible	.93 (.83 – .97)	ICC
	Latency to move phase 1	.94 (.85 – .98)	ICC
	Latency to follow C	.91 (.78 – .96)	ICC
	Score	.90	Kappa
Sociability	Latency to proximity to E	1.00 (.97 – 1.00)	ICC
	Latency to physical contact with E	.80 (.58 – .91)	ICC
	Duration of proximity to E (phase 1)	.99 (.96 – 1.00)	ICC
	Duration of physical contact with E (phase 1)	.92 (.77 – .97)	ICC
	Duration of proximity to E (phase 2)	1.00 (.99 – 1.00)	ICC
	Duration of physical contact with E (phase 2)	.99 (.96 – 1.00)	ICC
Call	Gazes at C	.83	Kappa
	Duration of gaze at C	.88 (.80 – .92)	ICC
	Time visible	.96 (.94 – .97)	ICC
Food begging	Success	.89	Kappa
	Gazes	.77	Kappa

Note. In italics ICC values < .7 and kappa values < .6. E = experimenter, C = caregiver

Table A.7

Descriptive statistics

Variable	N	Missing	Mean	Median	Standard deviation	Minimum	Maximum	Skewness	Std. error skewness	Kurtosis	Std. error kurtosis	Shapiro-Wilk W	Shapiro-Wilk p
Latency to gaze	95	17	12.10	4.00	17.70	0.00	60.00	1.95	0.25	2.60	0.49	0.65	<.001
Duration of gaze	95	17	16.00	12.40	13.80	0.00	54.40	0.72	0.25	-0.23	0.49	0.92	<.001
Relative latency gaze human	79	33	0.52	0.43	0.31	0.06	1.00	0.44	0.27	-1.27	0.54	0.88	<.001
Proportion attention human	79	33	0.18	0.11	0.21	0.00	0.94	1.53	0.27	2.29	0.54	0.83	<.001
Frequency gaze alternation	70	42	1.84	1.00	2.55	0.00	13.00	1.97	0.29	4.88	0.57	0.74	<.001
Relative latency gaze alternation	70	42	0.71	0.74	0.31	0.16	1.00	-0.42	0.29	-1.43	0.57	0.82	<.001
Frequency approach C after F	50	62	1.82	2.00	1.57	0.00	4.00	0.11	0.34	-1.59	0.66	0.84	<.001
Frequency approach social toy first	78	34	2.59	2.50	0.96	0.00	4.00	-0.08	0.27	-0.51	0.54	0.88	<.001
Frequency interact social toy first	60	52	2.27	2.00	0.94	0.00	4.00	-0.05	0.31	0.07	0.61	0.89	<.001
Average duration of proximity	77	35	38.80	40.60	15.40	1.40	58.80	-0.71	0.27	-0.33	0.54	0.93	<.001
Average proportion of social play	58	54	0.72	0.74	0.20	0.20	1.00	-0.68	0.31	-0.18	0.62	0.94	0.008
Relative synchronization	51	61	0.50	0.48	0.15	0.21	0.86	0.25	0.33	-0.65	0.66	0.98	0.463
Change-in-bias	43	69	0.19	0.17	0.26	-0.33	0.67	0.50	0.36	-0.63	0.71	0.89	<.001
Latency contact	93	19	28.50	8.60	37.70	0.80	120.00	1.43	0.25	0.85	0.50	0.73	<.001
Duration proximity phase 1	93	19	26.40	26.80	17.40	0.00	58.80	0.01	0.25	-1.07	0.50	0.95	0.002
Duration contact phase 1	93	19	9.92	7.80	9.68	0.00	37.00	0.98	0.25	0.35	0.50	0.89	<.001
Duration proximity phase 2	98	14	44.10	56.20	22.20	0.00	60.00	-1.21	0.24	-0.24	0.48	0.69	<.001
Duration contact phase 2	98	14	38.20	49.40	22.20	0.00	60.00	-0.85	0.24	-0.93	0.48	0.79	<.001

Note. C = caregiver, F = food

Table A.8

Descriptive statistics

Variable	N	Missing	Value	Counts	% of Total	Cumulative %
Frequency of gaze alternations	70	42	0	32	45.7 %	45.7 %
			1	10	14.3 %	60.0 %
			2	5	7.1 %	67.1 %
			3	10	14.3 %	81.4 %
			4	5	7.1 %	88.6 %
			5	3	4.3 %	92.9 %
			7	1	1.4 %	94.3 %
			8	3	4.3 %	98.6 %
Frequency of approaching C after F	50	62	0	16	32.0 %	32.0 %
			1	8	16.0 %	48.0 %
			2	5	10.0 %	58.0 %
			3	11	22.0 %	80.0 %
			4	10	20.0 %	100.0 %
Frequency of approaching social toy first	78	34	0	1	1.3 %	1.3 %
			1	7	9.0 %	10.3 %
			2	31	39.7 %	50.0 %
			3	23	29.5 %	79.5 %
			4	16	20.5 %	100.0 %
Frequency of interacting with social toy first	60	52	0	2	3.3 %	3.3 %
			1	8	13.3 %	16.7 %
			2	28	46.7 %	63.3 %
			3	16	26.7 %	90.0 %
			4	6	10.0 %	100.0 %
Movement in phase 1	85	27	0	43	50.6 %	50.6 %
			1	42	49.4 %	100.0 %
Proportion choosing large pre-test	43	69	0.5	14	32.6 %	32.6 %
			0.667	14	32.6 %	65.1 %
			0.8	9	20.9 %	86.0 %
			0.833	2	4.7 %	90.7 %
			1	4	9.3 %	100.0 %
Proportion choosing large test	43	69	0	2	4.7 %	4.7 %
			0.167	4	9.3 %	14.0 %
			0.333	10	23.3 %	37.2 %
			0.5	15	34.9 %	72.1 %
			0.667	5	11.6 %	83.7 %
			0.833	4	9.3 %	93.0 %
			1	3	7.0 %	100.0 %
OCT - success	87	25	1	5	5.7 %	5.7 %
			2	6	6.9 %	12.6 %
			3	32	36.8 %	49.4 %
			4	16	18.4 %	67.8 %
			5	17	19.5 %	87.4 %
			6	11	12.6 %	100.0 %
Call test - score	89	23	0	3	3.4 %	3.4 %
			1	37	41.6 %	44.9 %
			1.5	5	5.6 %	50.6 %
			2	44	49.4 %	100.0 %
Food begging test - Success score	82	30	0	6	7.3 %	7.3 %
			1	37	45.1 %	52.4 %
			1.5	16	19.5 %	72.0 %
			2	23	28.0 %	100.0 %
Food begging test - Gaze score	82	30	0	1	1.2 %	1.2 %
			1	46	56.1 %	57.3 %
			1.5	10	12.2 %	69.5 %
			2	25	30.5 %	100.0 %

Note. C = caregiver, F = food

Table A.9

Correlations within social motivation variables

		EYE CONTACT		UNSOLVABLE TASK			SEPARATION		PLAY			SYNCHRONIZATION		CONFORMITY	
		Latency	Duration	Latency Gaze Human	Proportion Attention	Frequency Alternation	Latency Alternation	Approach Owner	Approach Social	Interact Social	Duration Proximity	Proportion Social Play	Movement Phase 1	Relative Sync	Proportion Test
Duration	Correlation coefficient	-0.456**													
	Sig. (bilateral)	< .001													
	N	95													
Latency Gaze Human	Correlation coefficient	0.033	-0.169*												
	Sig. (bilateral)	0.693	0.039												
	N	72	72												
Proportion Attention	Correlation coefficient	0.007	0.144	-0.541**											
	Sig. (bilateral)	0.934	0.079	< .001											
	N	72	72	79											
Frequency Alternation	Correlation coefficient	0.050	0.036	-0.302**	0.332**										
	Sig. (bilateral)	0.598	0.703	< .001	< .001										
	N	64	64	70	70										
Latency Alternation	Correlation coefficient	-0.051	-0.062	0.403**	-0.329**	-0.765**									
	Sig. (bilateral)	0.579	0.495	< .001	< .001	< .001									
	N	64	64	70	70	70									
Approach Owner	Correlation coefficient	-0.012	-0.029	0.066	-0.109	0.070	0.012								
	Sig. (bilateral)	0.914	0.792	0.587	0.367	0.614	0.928								
	N	46	46	40	40	35	35								
Approach Social	Correlation coefficient	-0.039	0.012	-0.059	0.037	-0.037	0.007	-0.326*							
	Sig. (bilateral)	0.668	0.896	0.549	0.707	0.748	0.949	0.014							
	N	71	71	62	62	55	55	41							
Interact Social	Correlation coefficient	0.008	0.055	-0.045	0.027	-0.004	0.027	-0.186	0.898**						
	Sig. (bilateral)	0.936	0.592	0.678	0.805	0.972	0.827	0.244	< .001						
	N	57	57	50	50	43	43	29	60						
Duration Proximity	Correlation coefficient	0.057	0.007	0.183*	0.005	-0.089	0.062	-0.068	0.027	0.180					
	Sig. (bilateral)	0.490	0.931	0.040	0.955	0.388	0.534	0.570	0.759	0.070					
	N	70	70	61	61	54	54	40	77	60					
Proportion Social Play	Correlation coefficient	0.071	0.055	0.067	0.017	0.056	-0.053	-0.071	0.071	0.183	0.633**				
	Sig. (bilateral)	0.454	0.556	0.504	0.866	0.636	0.646	0.624	0.479	0.071	< .001				
	N	55	55	48	48	41	41	28	58	58	58				
Movement Phase 1	Correlation coefficient	0.069	-0.070	0.015	-0.100	0.178	-0.118	-0.087	0.086	0.182	-0.043	-0.047			
	Sig. (bilateral)	0.552	0.549	0.905	0.433	0.185	0.382	0.582	0.491	0.202	0.733	0.747			
	N	76	76	64	64	57	57	42	66	51	66	50			

Table A.9 (continued)

		EYE CONTACT		UNSOLVABLE TASK			SEPARATION		PLAY			SYNCHRONIZATION		CONFORMITY	
		Latency	Duration	Latency Gaze Human	Proportion Attention	Frequency Alternation	Latency Alternation	Approach Owner	Approach Social	Interact Social	Duration Proximity	Proportion Social Play	Movement Phase 1	Relative Sync	Proportion Test
Relative Sync	Correlation coefficient	0.037	0.119	0.059	-0.021	0.240	-0.269*	0.386*	0.032	0.154	0.006	0.040	0.547**		
	Sig. (bilateral)	0.723	0.257	0.605	0.850	0.066	0.035	0.012	0.799	0.327	0.958	0.774	< .001		
	N	44	44	38	38	34	34	25	38	26	37	26	43		
Proportion Test	Correlation coefficient	0.068	-0.054	0.042	-0.055	0.074	-0.081	-0.027	-0.156	0.041	0.063	0.027	-0.079	-0.323*	
	Sig. (bilateral)	0.584	0.658	0.745	0.670	0.631	0.589	0.879	0.304	0.812	0.644	0.862	0.643	0.043	
	N	38	38	35	35	29	29	22	32	25	32	25	37	23	
Change-in-bias	Correlation coefficient	0.045	0.051	-0.135	0.140	-0.022	-0.027	-0.079	0.217	-0.013	-0.043	-0.084	-0.016	0.223	-0.755**
	Sig. (bilateral)	0.708	0.671	0.286	0.263	0.885	0.853	0.652	0.143	0.938	0.748	0.577	0.927	0.149	< .001
	N	38	38	35	35	29	29	22	32	25	32	25	37	23	43

Note. * $p < .05$ ** $p < .001$

Table A.10*Correlation between sociability and social motivation variables*

		Latency Contact	Duration Proximity 1	Duration Contact 1	Duration Proximity 2	Duration Contact 2
EYE CONTACT - Latency	Correlation coefficient	0.054	-0.04	-0.045	0.042	0.081
	Sig. (bilateral)	0.474	0.599	0.558	0.583	0.271
	N	84	84	84	89	89
EYE CONTACT - Duration	Correlation coefficient	-0.149*	0.052	0.066	0.042	-0.013
	Sig. (bilateral)	0.048	0.486	0.387	0.578	0.864
	N	84	84	84	89	89
UNSOLVABLE TASK - Latency Gaze Human	Correlation coefficient	0.007	0.004	0.025	-0.106	-0.056
	Sig. (bilateral)	0.938	0.963	0.763	0.206	0.488
	N	69	69	69	74	74
UNSOLVABLE TASK - Proportion Attention	Correlation coefficient	-0.014	0.005	-0.021	0.123	0.052
	Sig. (bilateral)	0.868	0.954	0.803	0.14	0.518
	N	69	69	69	74	74
UNSOLVABLE TASK - Frequency Alternation	Correlation coefficient	0.109	-0.037	-0.045	0.105	0.164
	Sig. (bilateral)	0.263	0.702	0.643	0.278	0.081
	N	61	61	61	65	65
UNSOLVABLE TASK - Latency Alternation	Correlation coefficient	-0.089	0.012	0.035	-0.156	-0.179
	Sig. (bilateral)	0.345	0.901	0.712	0.097	0.051
	N	61	61	61	65	65
SEPARATION EPISODES - Approach Owner	Correlation coefficient	0.043	-0.186	-0.090	-0.049	-0.013
	Sig. (bilateral)	0.697	0.093	0.419	0.662	0.905
	N	47	47	47	48	48
PLAY - Approach Social	Correlation coefficient	-0.101	0.094	0.081	0.136	0.133
	Sig. (bilateral)	0.266	0.297	0.373	0.142	0.140
	N	73	73	73	74	74
PLAY - Interact Social	Correlation coefficient	-0.117	0.085	0.089	0.214*	0.238*
	Sig. (bilateral)	0.266	0.420	0.401	0.044	0.023
	N	55	55	55	56	56
PLAY - Duration Proximity	Correlation coefficient	-0.026	-0.003	0.028	-0.045	-0.011
	Sig. (bilateral)	0.744	0.969	0.736	0.588	0.894
	N	72	72	72	73	73
PLAY - Proportion Social Play	Correlation coefficient	0.038	-0.114	-0.103	-0.042	-0.038
	Sig. (bilateral)	0.687	0.227	0.278	0.660	0.689
	N	54	54	54	55	55
SYNCHRONIZATION - Movement Phase 1	Correlation coefficient	-0.030	0.008	0.092	0.002	0.056
	Sig. (bilateral)	0.794	0.941	0.420	0.984	0.617
	N	79	79	79	81	81
SYNCHRONIZATION - Relative Sync	Correlation coefficient	0.033	0.004	0.019	-0.026	0.009
	Sig. (bilateral)	0.748	0.971	0.853	0.800	0.924
	N	47	47	47	49	49
CONFORMITY - Proportion Test	Correlation coefficient	-0.074	0.180	0.058	0.165	0.211
	Sig. (bilateral)	0.538	0.132	0.629	0.181	0.080
	N	40	40	40	40	40
CONFORMITY - Change-in-bias	Correlation coefficient	0.120	-0.126	-0.070	-0.021	-0.098
	Sig. (bilateral)	0.308	0.281	0.549	0.864	0.407
	N	40	40	40	40	40

*Note . *p < .05*

Table A.11*Correlation between social cognition and social motivation variables*

		OCT	CALL TEST	FOOD BEGGING TEST	
		Success	Score	Success score	Gaze score
EYE CONTACT - Latency	Correlation coefficient	-0.104	0.003	-0.033	-0.024
	Sig. (bilateral)	0.223	0.975	0.711	0.798
	N	78	81	75	75
EYE CONTACT - Duration	Correlation coefficient	0.126	-0.049	0.064	0.095
	Sig. (bilateral)	0.141	0.583	0.477	0.3
	N	78	81	75	75
UNSOLVABLE TASK - Latency Gaze Human	Correlation coefficient	-0.049	-0.035	0.008	-0.074
	Sig. (bilateral)	0.585	0.721	0.935	0.461
	N	72	68	64	64
UNSOLVABLE TASK - Proportion Attention	Correlation coefficient	0.079	-0.118	-0.109	-0.02
	Sig. (bilateral)	0.378	0.228	0.267	0.84
	N	72	68	64	64
UNSOLVABLE TASK - Frequency Alternation	Correlation coefficient	-0.047	-0.029	-0.148	-0.088
	Sig. (bilateral)	0.647	0.798	0.192	0.447
	N	64	60	57	57
UNSOLVABLE TASK - Latency Alternation	Correlation coefficient	0.029	-0.062	0.194	0.123
	Sig. (bilateral)	0.777	0.574	0.077	0.273
	N	64	60	57	57
SEPARATION EPISODES - Approach Owner	Correlation coefficient	0.035	0.181	0.000	0.095
	Sig. (bilateral)	0.777	0.195	1.000	0.451
	N	45	41	49	49
PLAY - Approach Social	Correlation coefficient	-0.054	-0.027	0.243*	0.223*
	Sig. (bilateral)	0.584	0.807	0.022	0.042
	N	72	66	67	67
PLAY - Interact Social	Correlation coefficient	-0.006	-0.150	0.231	0.167
	Sig. (bilateral)	0.962	0.234	0.058	0.183
	N	55	51	51	51
PLAY - Duration Proximity	Correlation coefficient	0.125	-0.080	0.018	-0.053
	Sig. (bilateral)	0.160	0.423	0.849	0.592
	N	71	65	66	66
PLAY - Proportion Social Play	Correlation coefficient	0.135	-0.262*	0.012	0.033
	Sig. (bilateral)	0.189	0.023	0.911	0.775
	N	54	49	49	49
SYNCHRONIZATION - Movement Phase 1	Correlation coefficient	-0.131	-0.103	-0.090	-0.122
	Sig. (bilateral)	0.266	0.383	0.461	0.316
	N	74	74	70	70
SYNCHRONIZATION - Relative Sync	Correlation coefficient	0.182	-0.105	0.026	0.012
	Sig. (bilateral)	0.113	0.372	0.828	0.919
	N	44	46	44	44
CONFORMITY - Proportion Test	Correlation coefficient	0.012	0.231	0.022	-0.052
	Sig. (bilateral)	0.928	0.093	0.872	0.712
	N	39	40	39	39
CONFORMITY - Change-in-bias	Correlation coefficient	0.018	-0.263	-0.014	0.078
	Sig. (bilateral)	0.888	0.051	0.916	0.569
	N	39	40	39	39

Note . * $p < .05$

Table A.12*Correlation between social cognition and sociability variables*

		OCT	CALL TEST	FOOD BEGGING TEST	
		Success	Score	Success score	Gaze score
Latency Contact	Correlation coefficient	-0.016	-0.156	0.01	0.058
	Sig. (bilateral)	0.854	0.079	0.914	0.53
	N	79	82	75	75
Duration Proximity 1	Correlation coefficient	0.028	0.103	0.012	0.012
	Sig. (bilateral)	0.736	0.245	0.891	0.897
	N	79	82	75	75
Duration Contact 1	Correlation coefficient	0.04	0.153	-0.035	-0.038
	Sig. (bilateral)	0.640	0.09	0.701	0.688
	N	79	82	75	75
Duration Proximity 2	Correlation coefficient	0.126	-0.017	-0.071	-0.05
	Sig. (bilateral)	0.145	0.853	0.441	0.6
	N	81	85	77	77
Duration Contact 2	Correlation coefficient	0.038	0.051	-0.009	0.018
	Sig. (bilateral)	0.651	0.557	0.921	0.847
	N	81	85	77	77

Table A.13*Correlation within sociability variables*

		Latency Contact	Duration Proximity 1	Duration Contact 1	Duration Proximity 2
Duration Proximity 1	Correlation coefficient	-0.441**			
	Sig. (bilateral)	<.001			
	N	93			
Duration Contact 1	Correlation coefficient	-0.577**	0.702**		
	Sig. (bilateral)	<.001	<.001		
	N	93	93		
Duration Proximity 2	Correlation coefficient	-0.202*	0.286**	0.292**	
	Sig. (bilateral)	0.006	<.001	<.001	
	N	93	93	93	
Duration Contact 2	Correlation coefficient	-0.233*	0.235*	0.321**	0.716**
	Sig. (bilateral)	0.001	0.001	<.001	<.001
	N	93	93	93	98

*Note . *p < .05 ** p < .001***Table A.14***Correlation within social cognition variables*

		OCT - Success	CALL - Score	FOOD BEGGING Success score
CALL - Score	Correlation coefficient	-0.065		
	Sig. (bilateral)	0.521		
	N	76		
FOOD BEGGING - Success score	Correlation coefficient	0.075	0.014	
	Sig. (bilateral)	0.452	0.895	
	N	72	72	
FOOD BEGGING - Gaze score	Correlation coefficient	0.015	-0.005	0.755**
	Sig. (bilateral)	0.881	0.961	<.001
	N	72	72	82

*Note . ** p < .001*

Table A.15*Correlation between questionnaire factors and social motivation variables*

	N		Fearfulness	Aggression	Activity / Excitability	Companionability	Responsiveness
EYE CONTACT - Latency	95	Correlation coefficient	-0.083	-0.127	0.04	0.113	0.1
		Sig. (bilateral)	0.242	0.078	0.577	0.123	0.168
EYE CONTACT - Duration	95	Correlation coefficient	0.031	0.071	0.03	-0.096	0.014
		Sig. (bilateral)	0.662	0.319	0.673	0.186	0.851
UNSOLVABLE TASK - Latency Gaze Human	79	Correlation coefficient	-0.121	-0.057	-0.016	-0.021	-0.03
		Sig. (bilateral)	0.123	0.472	0.838	0.798	0.705
UNSOLVABLE TASK - Proportion Attention	79	Correlation coefficient	0.148	-0.015	0.065	0.073	-0.023
		Sig. (bilateral)	0.058	0.848	0.407	0.362	0.776
UNSOLVABLE TASK - Frequency Alternation	70	Correlation coefficient	0.140	0.151	-0.053	0.007	-0.059
		Sig. (bilateral)	0.122	0.099	0.558	0.940	0.519
UNSOLVABLE TASK - Latency Alternation	70	Correlation coefficient	-0.050	-0.107	0.033	-0.022	0.068
		Sig. (bilateral)	0.568	0.231	0.708	0.805	0.447
SEPARATION EPISODES - Approach Owner	50	Correlation coefficient	0.025	0.062	0.111	-0.135	0.115
		Sig. (bilateral)	0.816	0.567	0.304	0.221	0.294
PLAY - Approach Social	78	Correlation coefficient	-0.120	-0.019	-0.221*	0.095	-0.011
		Sig. (bilateral)	0.172	0.834	0.012	0.291	0.905
PLAY - Interact Social	60	Correlation coefficient	-0.120	0.001	-0.115	0.084	-0.035
		Sig. (bilateral)	0.231	0.989	0.258	0.417	0.732
PLAY - Duration Proximity	77	Correlation coefficient	-0.171*	-0.071	0.221*	0.102	-0.020
		Sig. (bilateral)	0.030	0.370	0.005	0.204	0.805
PLAY - Proportion Social Play	58	Correlation coefficient	-0.098	-0.074	0.151	0.018	-0.035
		Sig. (bilateral)	0.285	0.423	0.102	0.850	0.706
SYNCHRONIZATION - Movement Phase 1	85	Correlation coefficient	0.137	0.062	0.013	-0.082	-0.137
		Sig. (bilateral)	0.211	0.575	0.909	0.455	0.212
SYNCHRONIZATION - Relative Synchronization	51	Correlation coefficient	0.018	0.079	0.019	-0.208*	0.024
		Sig. (bilateral)	0.852	0.424	0.845	0.037	0.813
CONFORMITY - Proportion Test	43	Correlation coefficient	-0.069	-0.117	0.287*	0.087	0.005
		Sig. (bilateral)	0.552	0.318	0.013	0.465	0.965
CONFORMITY - Change-in-bias	43	Correlation coefficient	0.058	0.134	-0.253*	-0.082	0.035
		Sig. (bilateral)	0.607	0.246	0.026	0.483	0.763

*Note . *p < .05*

Table A.16*Correlation between questionnaire factors and sociability variables*

	N		Fearfulness	Aggression	Activity / Excitability	Companionability	Responsiveness
Latency Contact	93	Correlation coefficient	0.179*	0.151*	-0.007	-0.056	-0.043
		Sig. (bilateral)	0.013	0.037	0.926	0.448	0.56
Duration Proximity 1	93	Correlation coefficient	-0.181*	-0.109	-0.024	0.151*	0.015
		Sig. (bilateral)	0.011	0.131	0.737	0.04	0.836
Duration Contact 1	93	Correlation coefficient	-0.203*	-0.141	-0.015	0.163*	-0.014
		Sig. (bilateral)	0.005	0.056	0.841	0.029	0.846
Duration Proximity 2	98	Correlation coefficient	-0.188*	-0.199*	-0.037	0.224*	0.035
		Sig. (bilateral)	0.009	0.006	0.609	0.002	0.631
Duration Contact 2	98	Correlation coefficient	-0.195*	-0.167*	-0.047	0.238*	-0.022
		Sig. (bilateral)	0.006	0.019	0.505	0.001	0.76

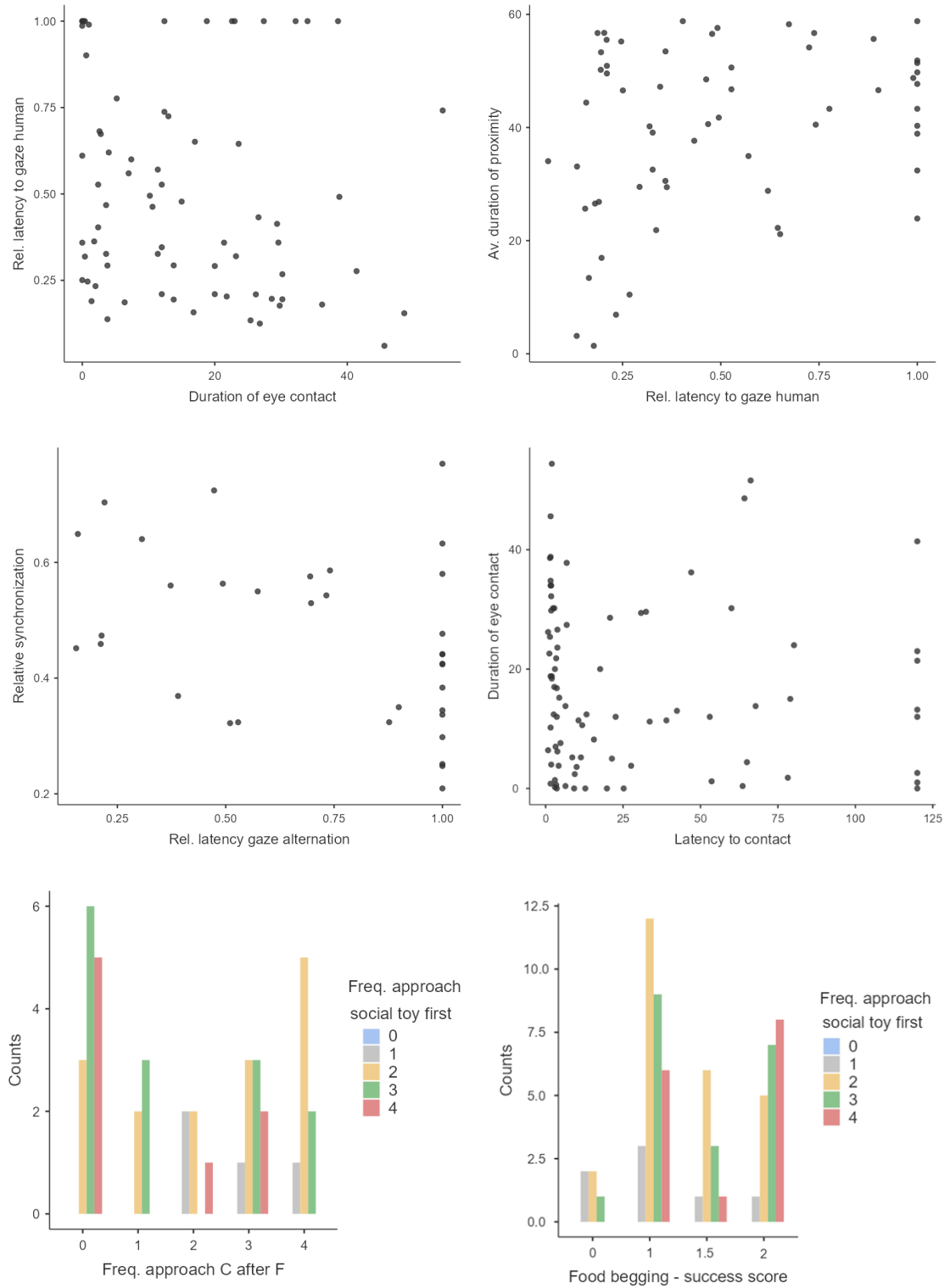
*Note . *p < .05***Table A.17***Correlation between questionnaire factors and social cognition variables*

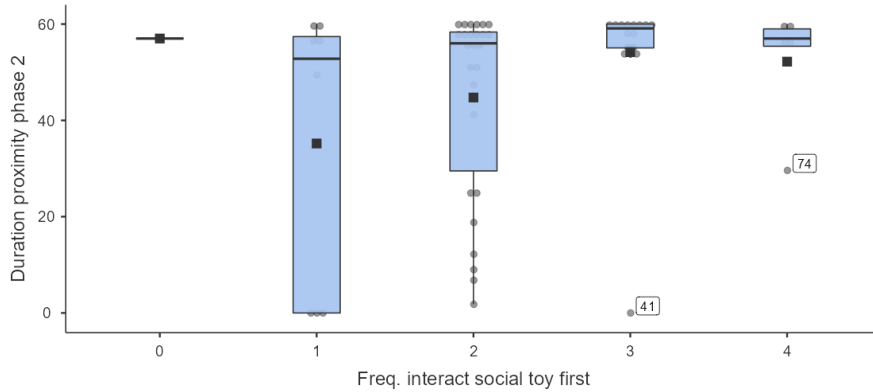
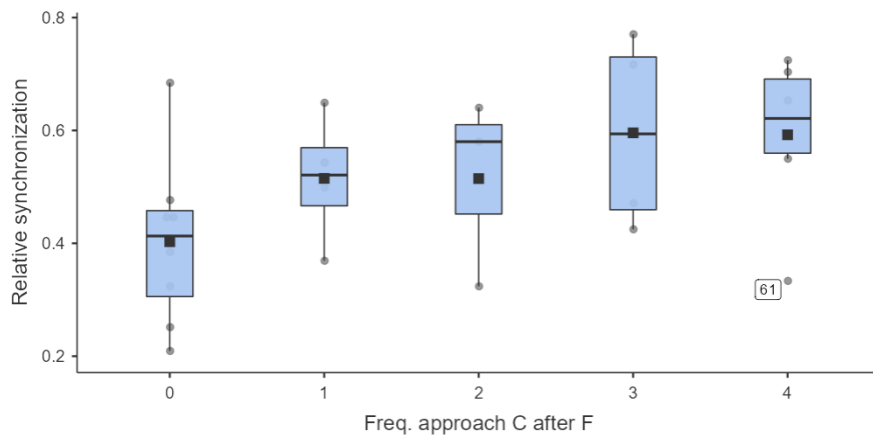
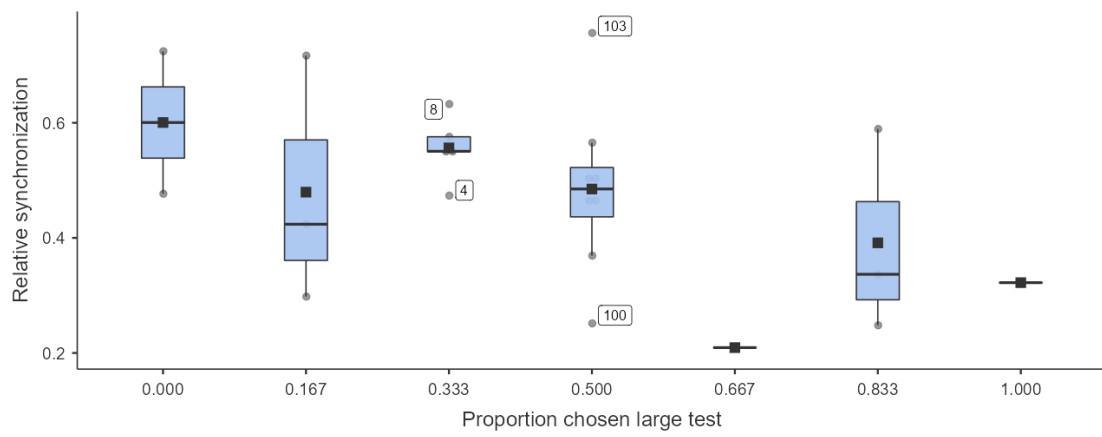
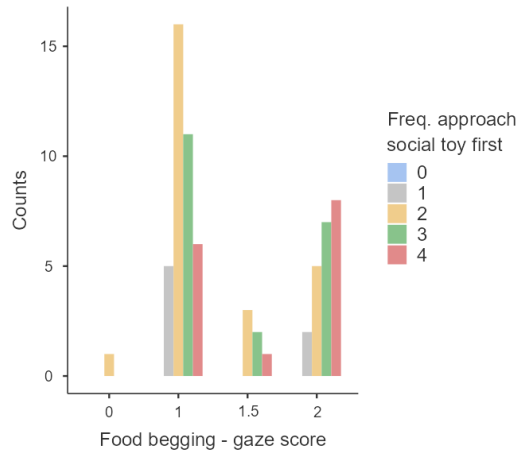
	N		Fearfulness	Aggression	Activity / Excitability	Companionability	Responsiveness
OCT - Success	87	Correlation coefficient	-0.05	-0.118	0.109	-0.076	-0.054
		Sig. (bilateral)	0.533	0.148	0.182	0.362	0.514
CALL - Score	89	Correlation coefficient	-0.117	-0.012	0.087	0.217*	0.172*
		Sig. (bilateral)	0.171	0.89	0.309	0.013	0.049
FOOD BEGGING - Success score	82	Correlation coefficient	-0.054	-0.024	-0.162	-0.058	0.001
		Sig. (bilateral)	0.534	0.784	0.062	0.51	0.99
FOOD BEGGING - Gaze score	82	Correlation coefficient	0.031	0.059	-0.206*	-0.008	0.039
		Sig. (bilateral)	0.728	0.509	0.02	0.928	0.668

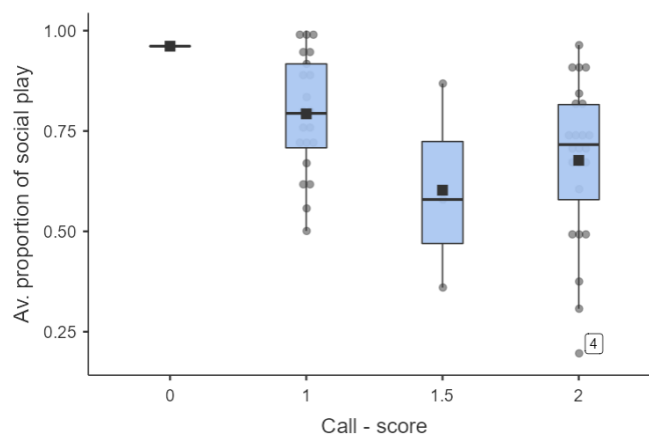
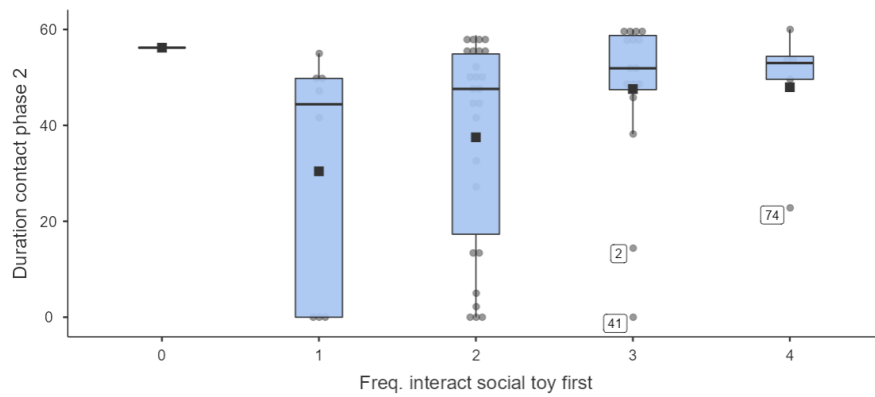
*Note . *p < .05*

Figure A.1

Scatterplots, bar plots and boxplots displaying the association between social motivation, sociability and social cognition variables



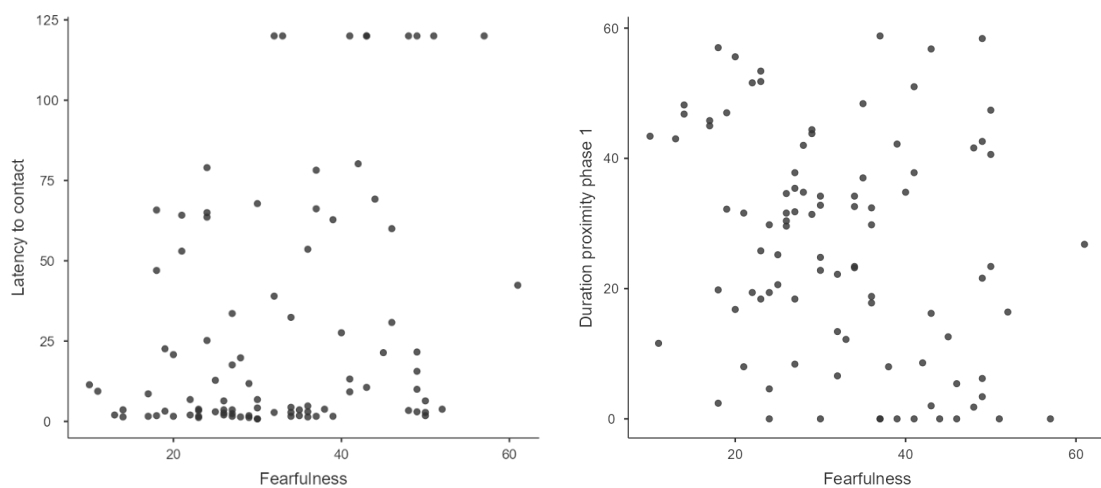


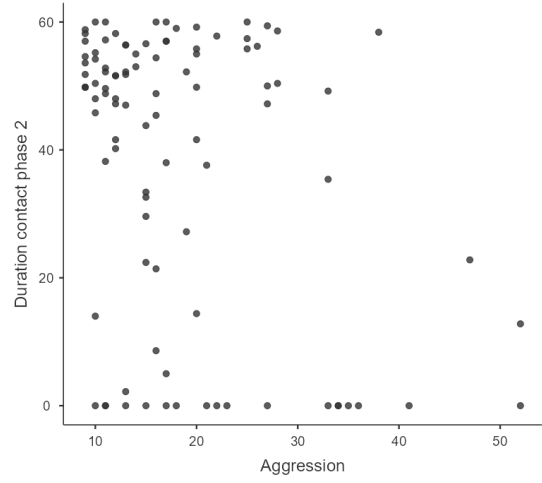
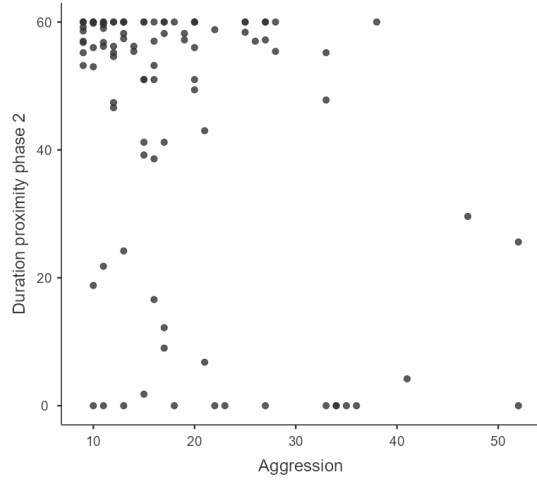
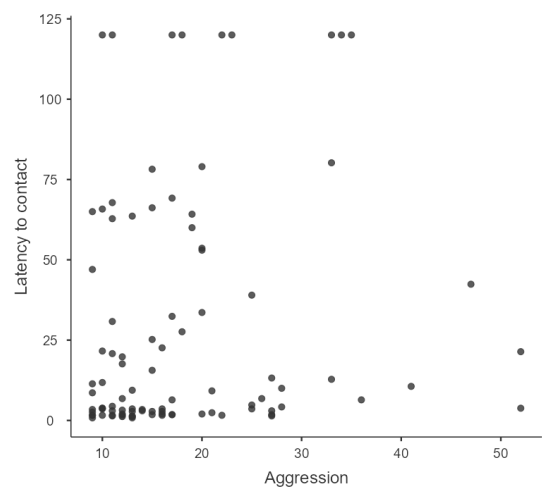
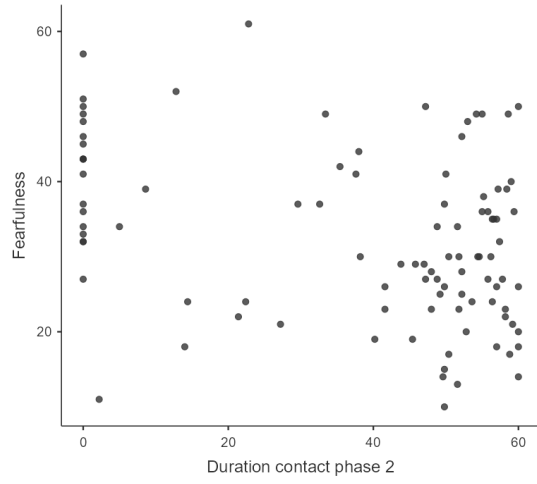
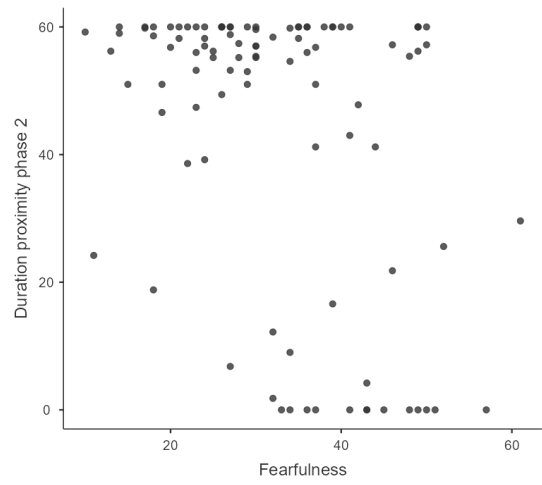
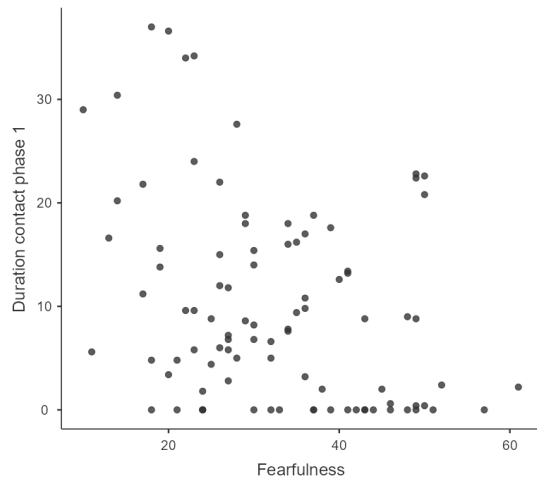


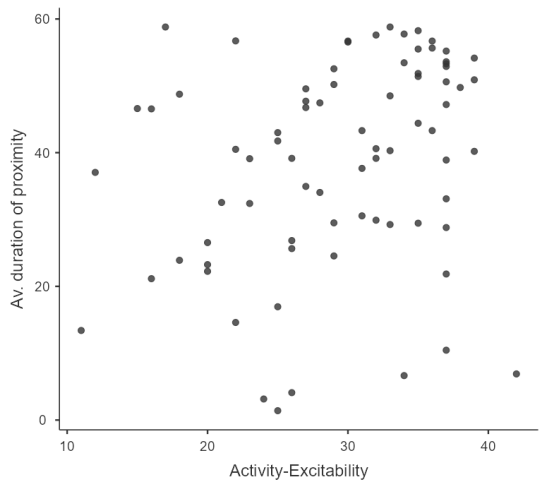
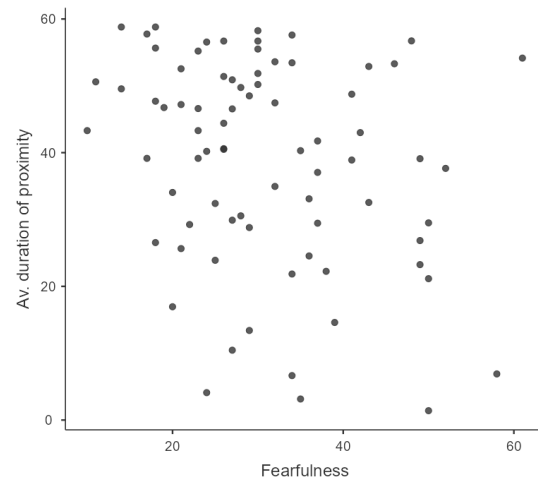
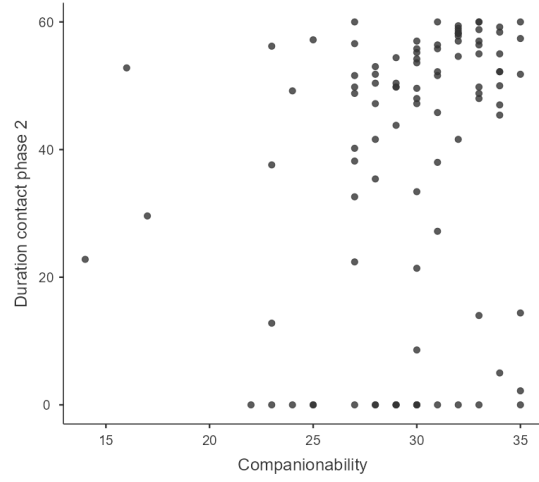
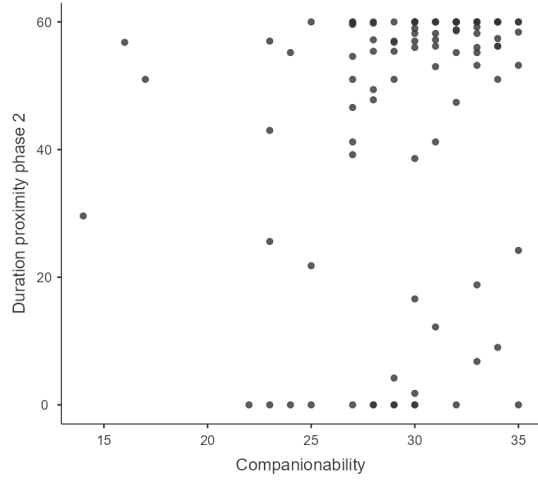
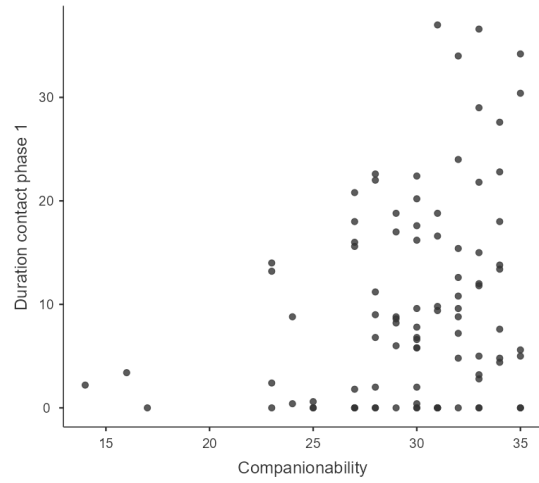
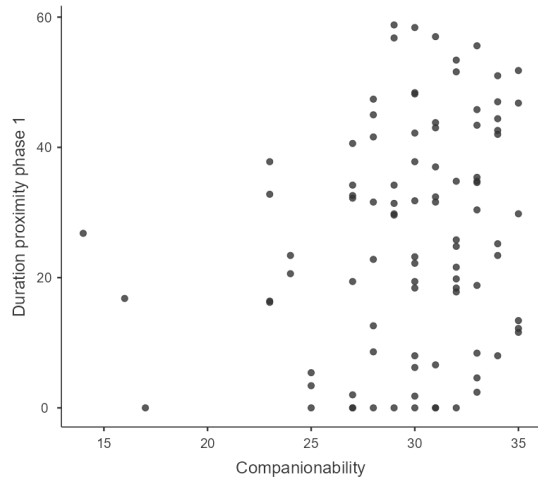
Note. Only significant correlations. Black squares in boxplots represent the mean; data points are presented and outliers are labelled.

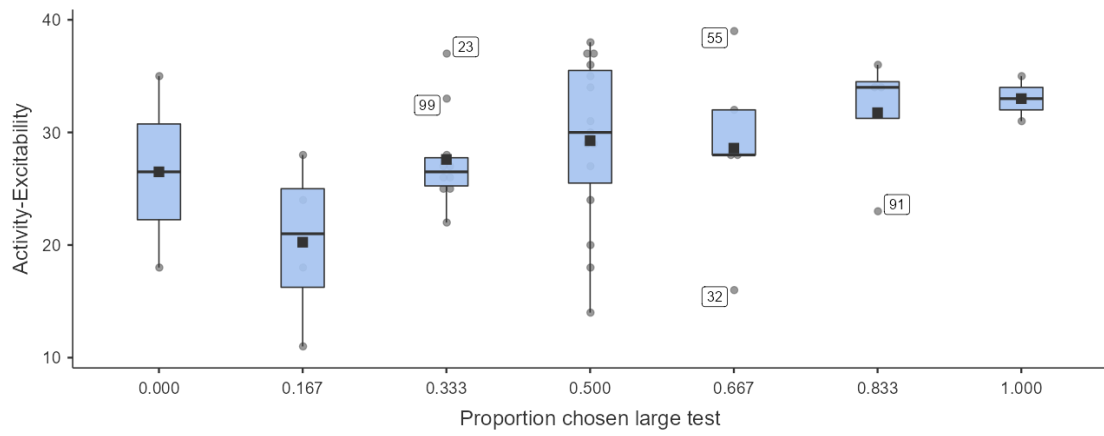
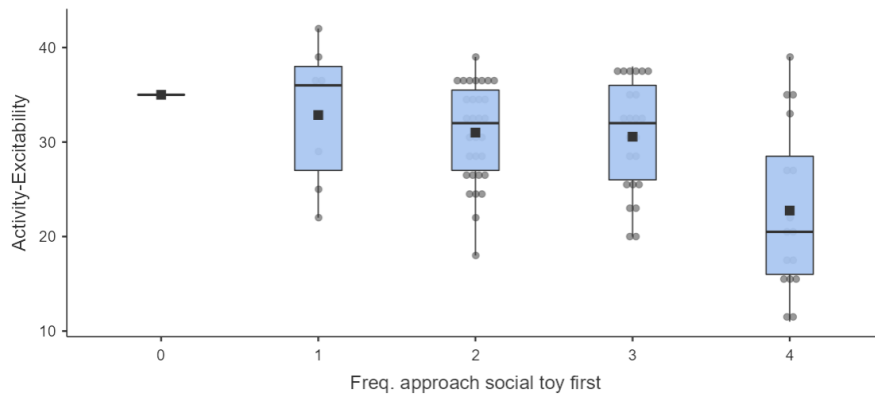
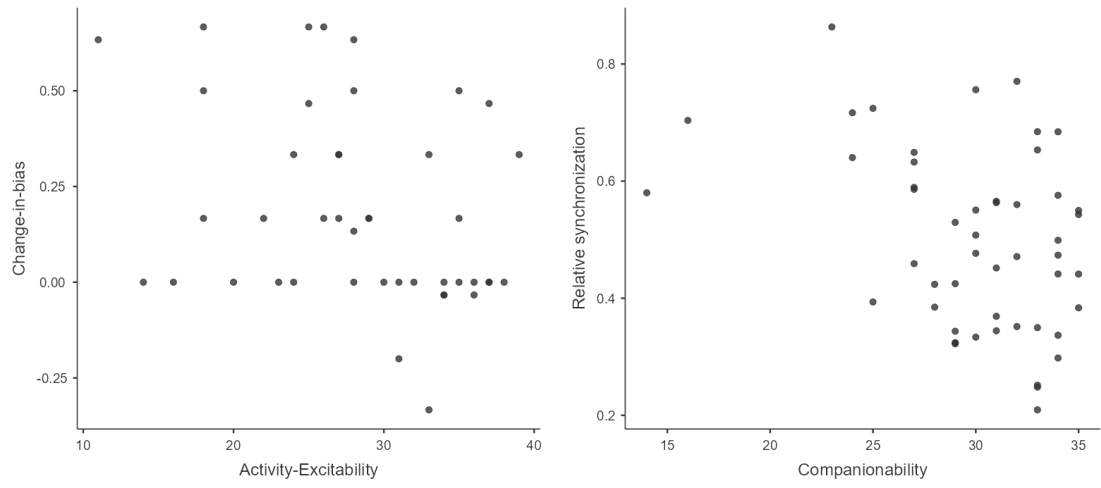
Figure A.2

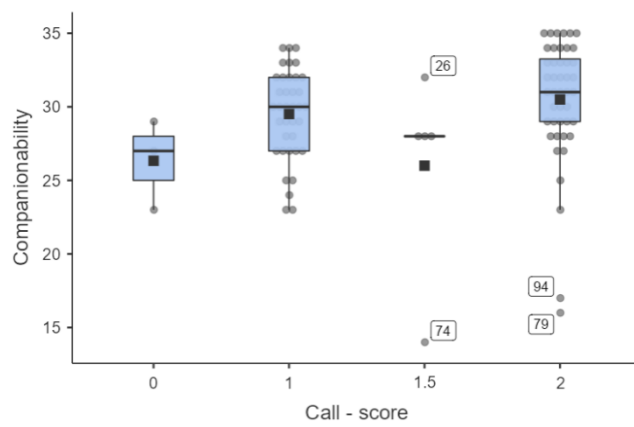
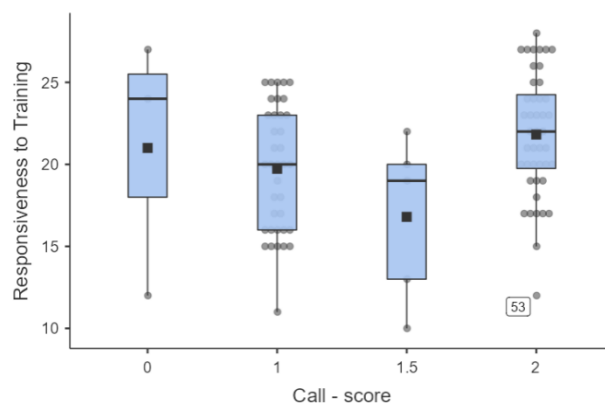
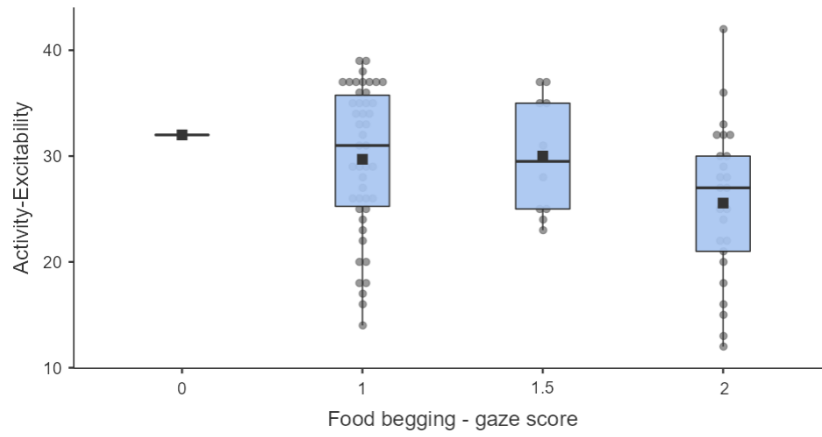
Scatterplots and boxplots displaying the association between the personality questionnaire factors and social motivation, sociability and social cognition variables











Note. Only significant correlations. Black squares in boxplots represent the mean; data points are presented and outliers are labelled.

Table A.18*Comparison of model fit indices from the 4-factor model and the original DPQ*

Fit Index	4-factor model fit estimate	Estimate original DPQ
CFI	.869	.556
TLI	.850	-
GFI	.839	.663
RMSEA	.064 [90% CI: (.053, .074)]	.068 [90% CI: (.067, .068)]

Table A.19*Standardized factor loadings of the 4-factor model*

Factor	Items	Standardized estimate	P (> z)
Fearfulness	i1	.342	< .001
	i5	.637	< .001
	i13	.793	< .001
	i22	.647	< .001
	i24	.609	< .001
	i12	.595	< .001
	i9	.343	< .001
	i28	.733	< .001
	i34	.449	< .001
	i14	.186	.101
Aggression towards people	i6	.844	< .001
	i10	.760	< .001
	i15	.675	< .001
	i32	.617	< .001
	i33	.665	< .001

Table A.19 (continued)

Factor	Items	Standardized estimate	P (> z)
Aggression towards people	i2	.329	< .001
	i8	.443	.001
	i19	.506	< .001
	i23	.136	.199
Activity/Excitability	i11	-.331	.011
	i25	-.164	.114
	i7	.188	.033
	i21	.077	.502
	i27	.149	.215
	i18	-.031	.765
	i3	.076	.425
	i16	.272	.099
	i20	.590	< .001
	i29	.281	.099
i31	.197	.082	
Responsiveness to Training	i17	.602	< .001
	i30	.670	< .001
	i4	.540	.001
	i26	.601	< .001

Note. In bold are loadings $\pm .40$

Table A.20*Correlations between factors in the 4-factor model*

Factors	Estimate	P (> z)
Fearfulness – Aggression towards People	.648	< .001
Fearfulness – Activity/Excitability	-.843	< .001
Fearfulness – Responsiveness to Training	-.151	.232
Aggression towards People – Activity/Excitability	-.691	< .001
Aggression towards People – Responsiveness to Training	.007	.964
Activity/Excitability – Responsiveness to Training	.278	.178

Note. In bold are significant correlations ($p < .05$)

Table A.21*Standardized factor loadings of the 5-factor model*

Factor	Items	Standardized estimate	P (> z)
Fearfulness	i1	.305	.002
	i5	.648	< .001
	i13	.796	< .001
	i22	.653	< .001
	i24	.615	< .001
	i12	.604	< .001
	i9	.341	.005
	i28	.725	< .001
	i34	.459	< .001
	i14	.174	.123
Aggression towards people	i6	.841	< .001
	i10	.760	< .001

Table A.21 (continued)

Factor	Items	Standardized estimate	P (> z)
Aggression towards people	i15	.668	< .001
	i32	.632	< .001
	i33	.671	< .001
	i2	.311	.016
	i8	.450	.001
	i19	.508	< .001
	i23	.151	.135
Activity/Excitability	i11	.378	< .001
	i25	.561	< .001
	i7	.564	< .001
	i21	.709	< .001
	i27	.565	< .001
	i18	.408	< .001
Companionability	i3	.175	.141
	i16	.440	.014
	i20	.794	< .001
	i29	.381	.027
	i31	.309	.013
Responsiveness to Training	i17	.537	< .001
	i30	.737	< .001
	i4	.568	< .001
	i26	.583	< .001

Note. In bold are loadings $\leq \pm .40$

Table A.22*Correlations between factors in the 5-factor model*

Factors	Estimate	P (> z)
Fearfulness – Aggression towards People	.642	< .001
Fearfulness – Activity/Excitability	-.147	.264
Fearfulness – Companionability	-.629	< .001
Fearfulness – Responsiveness to Training	-.140	.260
Aggression towards People – Activity/Excitability	.170	.094
Aggression towards People – Companionability	-.365	.017
Aggression towards People – Responsiveness to Training	.013	.925
Activity/Excitability – Companionability	.240	.156
Activity/Excitability – Responsiveness to Training	-.038	.804
Companionability – Responsiveness to Training	.075	.669

Note. In bold are significant correlations ($p < .05$)

Table A.23*Descriptive statistics of the dog personality questionnaire*

	N	Missing	Mean	Median	Standard deviation	Minimum	Maximum	Skewness	Std. error skewness	Kurtosis	Std. error kurtosis	Shapiro-Wilk W	Shapiro-Wilk p
Fearfulness	104	0	32.20	30.00	11.40	10.00	61.00	0.33	0.24	-0.56	0.47	0.98	0.084
Aggression			18.40	15.50	9.52	9.00	52.00	1.55		2.34		0.84	< .001
Activity-Excitability			28.80	29.50	7.06	11.00	42.00	-0.51		-0.37		0.97	0.009
Companionability			29.60	30.00	4.08	14.00	35.00	-1.36		2.63		0.90	< .001
Responsiveness to Training			21.00	21.00	4.34	10.00	28.00	-0.36		-0.55		0.97	0.016

Table A.24*Mean of the sociability clustering variables in the 2-cluster k-means solution*

Clustering variable	Mean original values		Mean standardized values	
	Cluster 1 (n = 70)	Cluster 2 (n = 22)	Cluster 1	Cluster 2
Duration of proximity phase 1	29.80	14.41	0.21	-0.72
Duration of proximity phase 2	56.08	7.56	0.51	-1.73

Table A.25*Mean of the sociability clustering variables in the 3-cluster k-means solution*

Clustering variable	Mean original values			Mean standardized values		
	Cluster 1 (n = 42)	Cluster 2 (n = 22)	Cluster 3 (n = 28)	Cluster 1	Cluster 2	Cluster 3
Duration of proximity phase 1	41.40	14.41	12.39	0.89	-0.68	-0.80
Duration of proximity phase 2	57.21	7.56	54.39	0.58	-1.68	0.45

Table A.26*Mean of the social motivation clustering variables in the 3-cluster solution*

Clustering variable	Mean original values			Mean standardized values		
	Cluster 1 (n = 31)	Cluster 2 (n = 5)	Cluster 3 (n = 8)	Cluster 1	Cluster 2	Cluster 3
Duration of eye contact	11.94	26.32	30.95	-0.36	0.66	0.99
Proportion of attention	0.13	0.53	0.07	-0.21	2.16	-0.56
Average proportion social play	0.80	0.76	0.48	0.33	0.11	-1.35

Table A.27*Mean of the social motivation clustering variables in the 3-cluster hierarchical solution*

Clustering variable	Mean original values			Mean standardized values		
	Cluster 1 (n = 42)	Cluster 2 (n = 12)	Cluster 3 (n = 14)	Cluster 1	Cluster 2	Cluster 3
Duration of eye contact	7.19	18.22	33.17	-0.56	0.29	1.44
Proportion of attention	0.10	0.44	0.09	-0.36	1.76	-0.43

Table A.28*Mean of the social motivation clustering variables in the 3-cluster hierarchical solution with average linkage*

Clustering variable	Mean original values			Mean standardized values		
	Cluster 1 (n = 27)	Cluster 2 (n = 8)	Cluster 3 (n = 10)	Cluster 1	Cluster 2	Cluster 3
Proportion of attention	0.08	0.08	0.38	-0.45	-0.42	1.55
Average proportion social play	0.80	0.43	0.84	0.30	-1.65	0.53

Table A.29*Mean of the social motivation clustering variables in the 3-cluster hierarchical solution*

Clustering variable	Mean original values			Mean standardized values		
	Cluster 1 (n = 35)	Cluster 2 (n = 7)	Cluster 3 (n = 13)	Cluster 1	Cluster 2	Cluster 3
Duration of eye contact	12.40	6.94	34.60	-0.32	-0.70	1.23
Average proportion social play	0.83	0.36	0.60	0.55	-1.72	-0.55

Table A.30*Mean of the social motivation clustering variables in the 4-cluster hierarchical solution*

Clustering variable	Mean original values				Mean standardized values			
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 1	Cluster 2	Cluster 3	Cluster 4
	(n = 10)	(n = 26)	(n = 7)	(n = 12)				
Duration of eye contact	27.12	6.98	6.94	35.92	0.71	-0.69	-0.70	1.32
Average proportion social play	0.94	0.78	0.36	0.60	1.07	0.32	-1.72	-0.58

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