Impulsivity and Behaviour Problems in Dogs: A Reinforcement Sensitivity Theory Perspective

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1. Introduction

Trait impulsivity is stirring growing interest among comparative researchers. One species where the trait is being extensively investigated is the domestic dog (*Canis familiaris*) (e.g. Miller et al., 2010, 2012; Fadel et al., 2016; Riemer et al., 2014; Wright et al., 2011, 2012). Research shows theoretical and evidential convergence between human and dog impulsivity. For example, consistent neuro-behavioural individual differences in cognitive control are found in dogs (Cook et al., 2016) as well as humans (e.g. Kane and Engle, 2002). Likewise, both in dogs and humans, self-control relies on biological mechanisms related to blood glucose levels (Miller, et al., 2010). There are also indications of human-dog convergence regarding genotype-phenotype associations for trait impulsivity (humans: Munafó et al., 2008; dogs: Hejjas et al., 2009; Wan et al., 2013). Impulsivity in dogs is also related to behaviours similar to human psychological disorders. For example, genetic and behavioural homologies between dogs and humans have been observed in relation to the Attention Deficit and Hyperactive Disorder (ADHD) (e.g. Hejjas et al., 2009; Vas et al., 2007), as measured in dogs through a rating scale for the assessment of ADHD in children, reworded for describing dog behaviour (Vas et al., 2007) and a behaviour battery (Kubinyi et al., 2012). Another typical case is the relationship between high impulsivity and aggressive behaviour, which has also been observed both in humans (Apter, et al., 1990) and dogs (Amat et al., 2013; Wright et al., 2012).

The current study brings together a biologically based human measure of impulsivity and a well validated dog measure of impulsivity, to investigate the extent to which the measures show convergence.

Trait impulsivity may be measured in domestic dogs with questionnaire scales, such as the Dog Impulsivity Assessment Scale (DIAS; Wright et al., 2011). The DIAS provides an overall questionnaire score (OQS), which directly reflects the dog owner's opinion on how impulsive their dog is and resulted to be higher in dogs with behaviour problems (Wright et al., 2011) as well as behavioural measures (Brady et al., 2018). However, the scale also provides three independent sub-factors, which can reflect distinct nuanced features of dog impulsivity. Factor 1, 'Behaviour Regulation' factor provides a more focused measure of impulsivity: high scores relates to having little control over a response to stimuli, little thinking before acting and being impatient, on the other side relates to showing extreme physiological signs when being excited. Factor 2, 'Aggression and Response to Novelty' relates to lower tolerance thresholds to potentially aversive stimuli: individuals with high scores are less keen on new situations and more likely to respond aggressively to stimuli. Factor 3, 'Responsiveness' relates to general responsiveness and environmental awareness: high scores reflect high trainability, long interest in stimuli and quick reactions (Wright et al., 2011). The scale was found to relate to variation in the behaviour observed in two systematically manipulated experimental designs, i.e. a delayed reward choice test (Wright et al., 2012) and, for the OQS and Factor 1, a spatial discounting test (Brady et al., 2018); correlations were found also between the DIAS scores and variation in physiological factors - i.e. serotonin metabolites (5-HIAA) levels (Wright et al., 2012). This suggests that the DIAS is a reliable measure of trait impulsivity in domestic dogs. Further investigations have indicated that DIAS scores and cognitive measures in behaviour tests remain stable over time, suggesting that personality trait of impulsivity is consistent over time (Riemer et al., 2014; Fadel et al., 2016).

In a broader sense trait impulsivity, as measured by the DIAS, may also be regarded as part of a wider network of theories investigating dispositional approach and avoidance behaviour. In this paper, we investigated how one such theory, the Reinforcement Sensitivity Theory (RST) of personality, might be of interest to research areas on dogs' individual differences.

RST is a neuropsychological account of the neural and cognitive processes underlying the major dimensions of personality (Corr, 2008). The theory describes three neurologically defined systems which influence the organism's behaviours; the Behavioural Approach System (BAS, activated by signals of reward), the Behavioural Inhibition System (BIS, related to the monitoring and resolution of conflict between compelling goals) and the Fight-Flight-Freeze System (FFFS, activated by aversive stimuli). The BAS has its neural basis in the dopaminergic reward circuitry (Pickering and Gray, 2001) and underlies any behaviour that involves approaching appetitive stimuli, whether it is to eat food or attack a prey. Because of this, the BAS is related to personality traits such as optimism, reward-orientation and impulsivity (Corr, 2004). The neural basis of the FFFS is the periaqueductal grey and medial hypothalamus (McNaughton and Corr, 2004). On a proximal level, the system is activated in response to aversive stimuli, encouraging active avoidance behaviours, and is responsible for personality traits such as proneness to fear (Corr & McNaughton, 2008). The BIS can be related to the septo-hippocampal system (Gray & McNaughton, 2000; Miller, 1991). The BIS is concerned with the monitoring and resolution of conflict between incompatible but equally compelling approach and avoidance goals. In humans, a strong presence of trait BIS is experienced as repetitive thoughts, rumination and anxiety (Andersen, Moore, Venables & Corr, 2008; Markarian, Pickett, Deveson & Kanona, 2013; Morgan et al., 2009). While low trait BIS is manifested as risk proneness and has been linked to Attention Deficit Hyperactivity Disorder (Gomez, Woodworth, Waugh & Corr, 2012).

RST is highly relevant to the non-human animal research as it was developed from experimental non-human animal behaviour research (Gray, 1987; Wilson, Barrett & Gray, 1989). In fact, several RST neurological studies have been performed on non-human animals, such as rodents (Ito & Lee, 2016; Young & McNaughton, 2008) and even AI programs have been coded using RST (Fua, Horswill, Ortony & Revelle, 2009). RST is especially useful when observing behaviour in non-verbalising species, as tendencies of approaching or avoiding aspects of the environment are readily codeable, in that behaviour measures may be unambiguous, such as increasing and decreasing of distances from a specific stimulus (see Budaev, 1997; Mather & Anderson, 1993). Finally, the strong focus on overt behaviour in experimental settings, such as go/no-go tasks, (Moore, Mills, Marshman & Corr, 2012) aids objective scoring of behaviour by human observers.

There are also some examples where elements drawn from RST have been employed in the development of frameworks directed, for example, to domestic animal research of affective states (Mendl, Burman & Paul, 2010) or individual differences in sensitivity to punishment and reward (Sheppards & Mills, 2002). To our knowledge, however, the RST of personality has not been applied in its entirety to companion animals' research (i.e. without integration within further theories). It is therefore not yet clear to which degree RST may be relevant to companion animals and whether there is any overlapping with existing theories. For this reason, it was of interest to place domestic dogs' trait impulsivity in an RST theoretical network.

Dogs were chosen as a species of interest because they are adapted to life with humans and share human social environment (Hare & Tomasello, 2002; Miklósi et al., 2003), which makes them an ideal and convenient model of comparison in the study of personality (Gosling et al., 2003). Additionally, the investigation of frameworks that are able to predict individual traits potentially linked to increased risk of developing behaviour problems in dogs has implications for animal welfare. For example, there are indications that aggressive behaviour in dogs may relate to neurotransmitters linked to impulsivity (Amat et al., 2013; Wright et al., 2012), a low BIS or high BAS-related trait. Aggressive responses may also be fear-related in dogs (van der Borg, Graat and Beerda, 2017; Zapata, Serpell and Alvarez, 2017), i.e. relevant to the FFFS. For example, tendency to engage in active avoidant behaviours like barking or growling could be seen as defensive behaviours, reflected in the FFFS. Or it could be the case that high trait BIS leads to better inhibition of destructive behaviour that may occur when the animal is distressed. Consistently with the theoretical link between impulsivity and behaviour inhibition, it has been observed that depletion of self-control is linked to risk proneness in dogs (Miller et al., 2012).

The current study brings together the DIAS (Wright et al., 2011) and a psychometric measure of RST (adapted from a children-focused scale; Cooper et al., 2017). As stated above, the principal reason for including both DIAS and RST measures is due to the mutual importance of trait impulsivity. We therefore predicted a positive association between the DIAS 'Behaviour

Regulation' trait (which is correlated with the spatial discounting test of impulsivity, Brady et al., 2018) and the RST BAS (which includes impulsivity) traits. Further, given that RST BIS is arguably the inverse of impulsivity and we expected this factor to negatively relate to the DIAS impulsivity measures. We had an exploratory approach regarding the relationship between the other factors of the RST and DIAS measures. Further we investigated the relationships between behavioural problems and the personality measures. Given that the DIAS was designed with behavioural problems in mind, we predicted that the DIAS traits predict behavioural problems. It was expected that FFFS would positively correlate with avoidance behaviours (e.g. biting, barking, cowering, trying to escape). We had no other explicit hypotheses for the relationship between the RST measures and the behavioural problems.

2. Material and Methods

2.1. Procedure & Questionnaires

The current study was approved by the University of Portsmouth's Science Faculty Ethics Committee (2017 - 026). The described work been performed in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Responses were provided anonymously by the participants. This work did not involve direct experimentation, observation or interaction with live animals and ethics was required for the data collection with animal owners.

After providing informed consent, participants completed the RST personality trait questionnaire. This measure was adapted from the 'Reinforcement Sensitivity Theory Personality Questionnaire - Child (RSTPQ-C, 21 items; Cooper et al., 2017): for the current study, the RSTPQ-C was reworded into a format that allowed owners to report on their dogs' behaviour, creating a Reinforcement Sensitivity Theory Personality Questionnaire-Dog (RSTPQ-D). Care was taken so that the RST system each question was referring to was not altered. In order to imitate the RSTPQ-C, the RSTPQ-D was also answered on a four-point scale with the options; *Not at all* (scoring 1), *Slightly* (2), *Moderately* (3) and *Highly* (4). The mean response to each of the RSTPQ-D subscales was used for analysis. The RSTPQ-D has 3 subscales of 7 items each, reflecting trait BIS, FFFS and BAS.

After completion of the RSTPQ-D, participants completed the 18 item DIAS. DIAS response is measured on a 5 point scale from *Strongly Agree* (5) to *Strongly Disagree* (1), with a sixth *Don't know/not applicable* option. Consistent with the scoring for the DIAS (Wright et al., 2011), each sub-factor was calculated as a ratio of the potential total score of items that had a response (due to the *Don't know* option, participants could opt to not respond to some items). The DIAS (Wright et al. 2011) has 3 factors, Factor 1 'Behavioural Regulation' (10 items, a high score implies higher trait impulsivity), Factor 2 'Aggression and Response to Novelty' (5 items, a high score suggests a more aggressive/aversive aversion to novelty) and Factor 3 'Responsiveness' (5 items, a high score implies fast and engaged responses to new things).

Finally, participants were asked to answer to a checklist of 12 further questions related to behaviour problems and indicate how well they described their dog's behaviour. Questions were presented in a 5-point scale, from *Very much like my dog* (5), to *Not at all like my dog* (1). Questions referred to aggressive behaviours (barking, growling, biting, showing teeth, snapping), cowering/fearful behaviour (shaking, panting, moving away), destructive behaviour (digging, chewing) and house soiling. A copy of the questionnaire is provided as Supplemental Information 1.

2.2. Participants

The inclusion criteria for dog owners to participate in the study were to be at least 18 years old and to have owned their dog for at least 6 months at the time they participated. Responses from owners of 730 adults dogs (age range: 1 - 16 years, median = 5 years, SD = 3.36, M : F =

1, neutered : intact = 6 : 1) were used for analysis. Dogs' demographic information is included in the Supplemental Information 2.

3. Results

3.1. Behaviour Checklist Factors.

Data were analysed using IBM SPSS Statistics version 22 and R (R Core Team, 2015). We examined the grouping of the behaviours listed in the checklist as it was expected that some behaviours may co-occur in some dogs. We first used an exploratory orthogonal (varimax) principal component analysis (henceforth 'EFA') with the loadings of the 12 behaviours. This suggested a four factor structure (Eigenvalue= 1.69, explaining 72% of variance) and grouped the behaviours in the checklist in the expected manner. A confirmatory factor analysis (henceforth 'CFA') further evidenced this (χ^2 (*df*= 48) = 153.90, $p < 0.001$, CFI= 0.97, RMSEA= 0.06). The four factors generated related to Active Avoidance (i.e. increasing distance from a perceived threat), Passive Avoidance (i.e. withholding interaction with a perceived threat), Destructive and Inappropriate Elimination Behaviours. Active Avoidance Behaviours consisted of frequency of Snapping (EFA loading= 0.89; CFA loading= 0.86), Biting (0.91; 0.92), Growling (0.82; 0.83) and Barking (0.74; 0.78). Passive Avoidance Behaviours constituted of frequency of Avoiding others (0.83; 0.95), Shaking (0.83; 0.96) and Panting (0.78; 0.87). Destructive Behaviours included frequent Damaging of objects (0.81; 0.71), Digging (0.72; 0.59) and Other Destructive behaviours (0.84; 0.76). Inappropriate Elimination related to reported Defecation (0.90; 0.52) and Urination (0.90; 0.74) at inappropriate locations. For further analyses, we retain aggregate response of the items for each factor, with a higher score indicating stronger endorsement of that behaviour. It is important to note that Inappropriate Elimination Behaviours were rarely endorsed (see Table 1) as were Destructive Behaviours (to a lesser extent). There was more variation in the Active and Passive Avoidance Behaviours but, on average, owners were more likely to disagree that these behaviours describe their dogs than agree (see Table 1).

3.2. Personality Factors.

We computed average score totals for the DIAS and RSTPQ-D. The RSTPQ-D retained an acceptable fit for its factor structure (21 items into three domains of FFFS, BIS and BAS) when applied to the owner's ratings of dogs (CFA: χ^2 (df= 186) = 1001.94, p < 0.001, CFI= 0.88, RMSEA= 0.08). The descriptive statistics for these personality factors can be found in Table 1. Given that both these data and those of the behaviours are considered non-normal by Kolmogorov-Smirnov testing (table 1), we investigate relationships between our variables using Spearman's rho correlations. In order to correct for multiple comparisons, the significance level has been corrected for the number of comparisons, therefore a significance level of alpha = 0.002 was accepted (alpha = 0.05 / 24).

The RSTPQ-D's BAS measure positively correlated with the DIAS' Responsiveness (r_s(730)= 0.46, 95% *CI* [0.40, 0.53], p< 0.001), this suggests that the RST's BAS has a similar function to the DIAS' Responsiveness trait. There were small negative correlations with the DIAS' Aggression/Response to Novelty (r_s(730)= -0.19, 95% *CI* [-0.26, -0.12], p< 0.001) and Behavioural Regulation (r_s(730)= -0.12, 95% *CI* [-0.19, -0.05], p= 0.002).

There was a notable negative correlation between the RSTPQ-D's BIS and the DIAS' Behavioural Regulation factor (r_s(730)= -0.30, 95% *CI* [-0.37, -0.22], p< 0.001), reflecting that reported impulsivity is in opposition to reported inhibition. There were much weaker correlations with the DIAS' Aggression/Response to Novelty (r_s(730)= 0.15, 95% *CI* [0.08, 0.23], p< 0.001) and Responsiveness (r_s(730)= -0.08, 95% *CI* [-0.15, -0.01], p= 0.024) factors.

The RSTPQ-D's FFFS factor was largely distinct to the DIAS factors. It did not notably correlate with Behavioural Regulation (r_s(730)= -0.02, 95% *CI* [-0.10, 0.06], p= 0.531), Aggression/Response to Novelty (r_s(730)= 0.04, 95% *CI* [-0.03, 0.12], p= 0.243) or Responsiveness (r_s(730)= -0.12, 95% *CI* [-0.20, -0.04], p= 0.002). Overall, RST's FFFS and the DIAS' Aggression/Response to Novelty did not correlate with the behavioural factors. Both FFFS and Aggression/Response to Novelty relate to avoidance-style behaviours and this result would suggest that they relate to different aspects of behavioural avoidance. Fig 1. provides a visual overview of the relationships between the trait factors.

3.3. Personality and Behaviours.

One aim of this study was to identify personality traits that related to common problem behaviours in dogs. The correlations between personality and behaviours are reported in Table 2. Overall the DIAS better reflects problem behaviours than the RSTPQ-D. There are notable correlations between DIAS' Behavioural Regulation (impulsivity measure) and the more overt Active Avoidance and Destructive Behaviours. DIAS' Aggression/Response to Novelty positively correlated with both the Active and Passive Avoidance Behaviours, implying that a trait aversion to novel stimuli was more likely to lead to behavioural avoidance. DIAS' Responsiveness showed no noteworthy correlations with the behaviours.

The RSTPQ-D had smaller correlations with the Behaviours than the DIAS. However, the FFFS trait did positively correlate with Passive Avoidant traits and (weakly) negatively with Active Avoidance traits and the difference in the size of these two correlations is notably large (Fisher's *Z*' test= 7.76, $p<0.001$). This suggests that the FFFS trait may reflect an axis of Active to Passive Avoidant Behaviour and offer more discriminability in the *style* of avoidance behaviour than the DIAS traits. BIS and BAS largely did not correlate with the behaviours.

4. Discussion

The current study investigated the overlap between measures of domestic dog impulsivity (DIAS) and a broader cross-species theory of individual differences in approach/avoid behaviour, Reinforcement Sensitivity Theory (Gray and McNaughton, 2000). Our results show that, in dogs, RST trait inhibition (BIS) is the inverse to impulsivity, as measured by the DIAS Behavioural Regulation, as hypothesised. Another interesting result is the positive relationship between BAS and Responsiveness, as predicted. The DIAS Responsiveness factor contains behaviours related to high trainability, interest in the environment and quick reactions (Wright et al., 2011). Such behaviours intuitively relate to trait BAS, which promotes reward seeking and goal-oriented behaviours (Corr, 2004). These findings suggest that the RST theoretical framework can be used to complement the DIAS tool.

None of the DIAS facets related with the RST trait FFFS. FFFS did demonstrate a small positive correlation with the Passive Avoidance behaviour problems and a negative relationship with the Active Avoidance. From this, we see that FFFS is largely distinct from the DIAS model but it may potentially have predictive value for fear-related behavioural problems in dogs, such as aggression (in line with previous findings on dog aggression: Amat et al., 2013; Wright et al., 2012). According to RST, FFFS is related to the Fight-Flight-Freeze response, which reflects defensive avoidance strategies based on the perceived intensity of a threat. Threat perception may be measured in terms of defensive distance, i.e. distance from a threat that causes various defensive behaviours (Blanchard and Blanchard, 1988). The smallest defensive distances result in explosive attack (fight response), while intermediate defensive distances lead to flight and freeze (Blanchard and Blanchard, 1988; McNaughton and Corr, 2004). Interestingly, an alternative measure of individual differences in dogs, the PANAS scale (Positive and Negative Activation Scale, Sheppard and Mills, 2002), is partially driven from an RST scale based on an earlier version of the framework (Carver and White, 1994) and measures dogs' sensitivity to reward and to punishment, which reflects the directional component of the most recent version of RST (Gray and McNaughton, 2000). Given the current results, investigating how the PANAS relates with the updated FFFS domain would provide further evidence of the applicability of RST to the investigation of dog behaviour.

The relationship between DIAS-Behaviour Regulation and Active Avoidance / Destructiveness (both characterised by high activity levels) also suggests that such behaviours might relate to mechanisms such as frustration and lack of self-control. Such a possibility is in line with the human literature, where low BIS is associated with risk proneness and ADHD (Gomez, Woodworth, Waugh & Corr, 2012) and the canine literature, where high impulsivity, as measured with the DIAS, is associated with aggressive behaviour (Wright et al., 2012). While it is not possible to draw conclusions on similar patterns in dogs, given the established similarities between human and dog ADHD (Hejjas et al., 2009; Kubinyi et al., 2012; Vas et al., 2007), it may be also of interest to understand whether RST relates with the existing measures of canine ADHD.

Overall, the current results highlight how RST might be potentially of interest for the investigation of dogs' individual differences, especially in the investigation of approach and avoidance behaviour. We suggest that the questions relating to the FFFS factor of the RSTPQ-D could integrate the existing DIAS scale. We also suggest that future research should look further into how RST framework may be used to interpret results obtained from the DIAS. In order to further explore this possibility, future research on the relationship between RST and trait dog behaviour should be investigated through behavioural experiments, providing direct observation of behaviour under systematic manipulation. Various existing experimental paradigms have indicated individual differences in dogs based on approach and avoidance behaviours (e.g. cognitive bias test, Starling et al., 2014; response to threat, Vas et al., 2008). There is also evidence that difference in persistence affects dogs' strategies when trying to retrieve a food reward in the presence of a cognitive conflict, such as in the so-called *unsolvable task* (Marshall-Pescini et al., 2017). Finally, several experimental tasks have been developed to measure inhibitory control in dogs (which is supposedly related to impulsive behaviour as measured by the DIAS, Wright et al., 2011), suggesting a subdivision in persistency, compulsivity and decision speed (Brucks et al., 2017). This subdivision suggests it may be of interest to investigate how the result of these behaviour tests relate with the RST domains. Given the existing strong neurobiology basis of RST, it is also worthy to consider that behavioural findings should be followed up by electrophysiological measures, typical of the RST literature - for example, in humans, behaviour tests based on go/no go and stop signal tasks are paired with EEG measurements (Brier et al., 2010; Moore et al., 2012; Shadli, Glue, McIntosh & McNaughton, 2015). Finally, RST work could also be extended to other non-human species where individual differences research focuses on approach-avoid behaviours (e.g. birds: Meier et al., 2017; sheep: Beausoleil et al., 2005; sharks: Byrnes and Brown, 2016; Finger et al., 2016; minks: Malmkvist et al., 2003)

The current study revolves on data coded by dog-owners rather than direct observations of dogs' behaviour, which may be considered a limitation of the presented work. Although care was taken to avoid questions on "internalised" processes, it should be understood that the responses reflect the owner's interpretation of their dog's behaviour. However, previous research indicates that dog owners are relatively reliable in describing their dogs' behaviour (Gosling et al., 2003). Additionally, the DIAS scale has been validated against experimental measures and for consistency over time (Wright et al., 2011; Riemer et al., 2014; Fadel et al., 2016). Moreover, the aim of the current study was to measure correlations between the two scales, RSTPQ-D and DIAS, rather than informing on the validity of an RST measure in itself. Validation should be in fact a consideration for future studies.

Another consideration regards the relatively small correlations observed between the RST and the DIAS factors. This may suggest that part of the observed variance might be attributable to external factors (Ferguson, 2009) not considered in this study, such as breed differences or training experience. These and other potential confounders should be evaluated in the future.

Finally, it is noteworthy that the current findings support the idea that investigating the potential applications to RST to non-human animals may provide benefits also to animal welfare. Versions of RST scales (e.g. Carver and White, 1994; Gray 1994; McNaughton & Corr, 2008) have been beneficial to the development of frameworks, based on approach and avoidance, to be used in non-human animal research (e.g. Sheppard and Mills, 2002; Mendl et al., 2010), providing evidence that RST may be relevant to companion animals in general and dogs specifically. For example, research based on measuring dogs' tendency to approach rewarding stimuli and avoid unpleasant ones, has led to the demonstration of a negative cognitive bias in dogs affected by separation related issues (Burman et al., 2009). Additionally, a scale (PANAS), which partially draws from an earlier version of RST, proved to be useful in measuring sensitivity to reward and punishment in dogs, which is particularly relevant to predict the success of dog training or veterinary behaviour medicine interventions (Sheppard and Mills, 2002). Indeed, RST provides a theoretical framework grounded on neurobiological evidence to understand traits related to behaviour issues, such as impulsive behaviour or anxiety. The partial overlapping between the RSTPQ-D and the DIAS and the relationship of the FFFS facet with reported behaviour issues potentially related to fear and anxiety (avoidance behaviours) further advocates for the investigation of RST as a tool to understand companion animals' behaviour. Given the necessary validation, RST might, in the future, aid the selection of treatments in clinical cases through a better distinction between FFFS-fear behaviours and BIS-anxiety behaviours, in line with the definitions provided by Gray and McNaughton (2000), especially in those cases characterised by immobility as behavioural response, which might reflect freezing behaviour (activation of FFFS) or conflict (activation of BIS). Again, RST has proved to be beneficial in human psychology for the identification of markers for the risk to develop psychological disorders (e.g. anxiety, Shadli et al., 2015); similar research directions could be explored in veterinary behaviour medicine, especially in the presence of other known environmental risk factors, such as dogs adopted from pet shops or shelters (Cannas et al., 2017). Nevertheless, benefits may be extended also to other species, even beyond domestic animals. For example, inhibitory control in a stop-signal task has been linked to increased fit and survival in pheasants (Whiteside et al., 2016).

4.1. Conclusion

In conclusion, the findings of this work suggest an overlap between RST and the constructs of trait impulsivity in dogs (as measured by the DIAS). However, this is a starting point, the aim of which is to suggest RST as a useful framework for the cross-specific investigation of individual differences. Future experimental and large scale personality studies will allow for the comprehensive framework of RST to contribute to the literature on dogs' and other non-human animals' welfare and behaviour.

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Compliance with Ethical Standards

Conflict of Interest: Patrizia Piotti declares that she has no conflict of interest. Liam Satchell declares that he has no conflict of interest. Tom Lockhart declares that he has no conflict of interest.

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Tables:

Table 1. The descriptive statistics of the critical behavioural and personality variables in this study

Variable	Mean	SD	Skewness	Kurtosis	Kolgmorov-Smirnov test
Behaviours					
Active Avoidance Behaviours	1.93	0.93	1.25	1.44	0.16**
Passive Avoidance Behaviours	2.20	1.05	0.67	-0.25	0.13**
Destructive Behaviours	1.74	0.82	1.20	1.12	0.19**
Inappropriate Elimination Behaviours	1.34	0.71	2.62	7.76	0.41**
Traits					
Reinforcement Sensitivity Theory Personality Questionnaire - Dog					
Behavioural Approach System	3.81	0.81	-0.58	-0.08	0.09**
Behavioural Inhibition System	2.92	1.07	-0.04	-0.89	0.07**
Fight/Flight/Freeze System	2.46	0.84	0.29	-0.23	0.05**
Dog Impulsivity Assessment Scale					
Behavioural Regulation	2.78	0.78	-0.13	0.10	0.05*
Aggression/Response to Novelty	2.07	0.78	0.51	-0.14	0.12**
Responsiveness	3.63	0.59	-0.21	-0.01	0.09**
Overall Questionnaire Score	2.88	0.51	0.19	-0.35	0.05*

Notes: *p=.001, **p<.001

Table 2. Spearman's correlations between the behaviour and personality trait variables (absolute *p* values in brackets) [95% CI in square brackets]

Traits	Active Avoidance Behaviours	Passive Avoidance Behaviours	Destructive Behaviours	Inappropriate Elimination Behaviours
Reinforcement Sensitivity Theory Personality Questionnaire - Dog				
Behavioural Approach System	-0.08 (=0.032) [-0.15, -0.00]	-0.11 (=0.002) [-0.18, -0.04]	0.01 (=0.965) [-0.08, 0.08]	-0.04 (=0.281) [-0.12, 0.05]
Behavioural Inhibition System	-0.00 (=0.961) [-0.08, 0.08]	**0.16** **(<0.001)** **[0.08, 0.23]**	**-0.15** **(<0.001)** **[-0.24, -0.08]**	0.06 (=0.113) [-0.02, 0.13]
Fight/Flight/Freeze System	**-0.14** **(<0.001)** **[-0.22, -0.06]**	**0.26** **(<0.001)** **[0.19, 0.34]**	0.03 (=0.360) [-0.04, 0.11]	0.11 (=0.002) [0.02, 0.19]
Dog Impulsivity Assessment Scale				
Behavioural Regulation	**0.34** **(<0.001)** **[0.27, 0.40]**	**0.17** **(<0.001)** **[0.09, 0.24]**	**0.30** **(<0.001)** **[0.23, 0.36]**	**0.22** **(<0.001)** **[0.15, 0.29]**
Aggression/Response to Novelty	**0.53** **(<0.001)** **[0.45, 0.57]**	**0.48** **(<0.001)** **[0.38, 0.50]**	0.10 (=0.005) [0.02, 0.17]	**0.13** **(<0.001)** **[0.04, 0.18]**
Responsiveness	-0.034 (=0.319) [-0.11 0.04]	-0.11 (=0.003) [-0.18, 0.04]	0.03 (=0.415) [-0.04, 0.11]	-0.03 (=0.431) [-0.10, 0.05]
Overall Questionnaire Score	**0.40** **(<0.001)** **[0.34, 0.46]**	**0.18** **(<0.001)** **[0.12. 0.26]**	**0.29** **(<0.001)** **[0.23, 0.36]**	**0.20** **(<0.001)** **[0.13, 0.26]**

Notes:
Bold = p< 0.002 (corrected alpha level of 0.05 over 24 comparisons)

Figures:

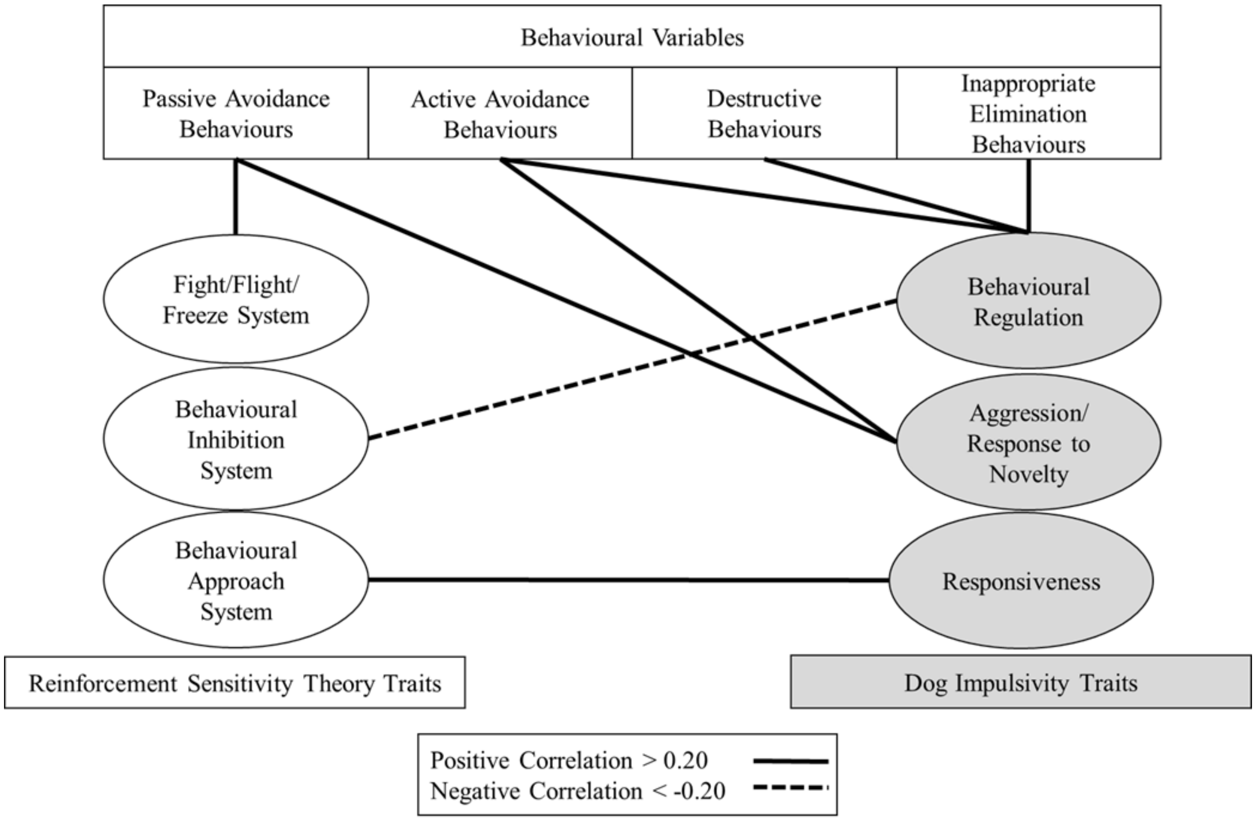

Fig 1. Overview of the relationships between the behavioural and trait (from the Reinforcement Sensitivity Theory Personality Questionnaires and Dog Impulsivity Assessment Scale) factor variables in the study. Spearman rho's correlations, with r above 0.20 are shown ($p < 0.002$ – corrected alpha level of 0.05 over 24 comparisons; r cut-off was selected based on Ferguson, 2009).

Supplemental information 1

Reinforcement Sensitivity Theory of Personality Questionnaire - Dog

		Strongly disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Strongly agree
1.	My dog would be frozen to the spot if there was a dangerous animal in the house with him/her.	1	2	3	4	5
2.	My dog would be frozen to the spot if he/she saw a large shadow when swimming.	1	2	3	4	5
3.	My dog would run away if he/she saw a dangerous animal.	1	2	3	4	5
4.	My dog would freeze if he/she thought a something was going to attack him/her.	1	2	3	4	5
5.	My dog would freeze if he/she heard scary noises at night.	1	2	3	4	5
6.	My dog would run away from an animal if it was making her/him feel scared.	1	2	3	4	5
7.	My dog would run upstairs if there was something scary downstairs.	1	2	3	4	5
8.	My dog is careful when doing something that might hurt him/her.	1	2	3	4	5
9.	My dog would be careful when playing.	1	2	3	4	5
10.	My dog would stop what he/she was doing if he/she thought there was physical danger or he/she might hurt him/herself.	1	2	3	4	5
11.	My dog would stop what he/she was doing if he/she thought it was too risky to keep going.	1	2	3	4	5
12.	My dog worries about getting hurt.	1	2	3	4	5
13.	My dog would stop and think before going down a steep slope or sharp drop (where they would not be able to stop easily).	1	2	3	4	5
14.	My dog appears to stop and think carefully before trying out for something.	1	2	3	4	5
15.	My dog spends a lot of time trying to get better at things he/she likes doing (such as fetch/agility).	1	2	3	4	5
16.	My dog works hard to do well at the things they like doing (like playing ‘find it’ or ‘fetch’).	1	2	3	4	5
17.	My dog likes to practice something he/she likes doing.	1	2	3	4	5
18.	My dog puts in lots of effort to achieve a goal (or get what he/she wants).	1	2	3	4	5
19.	My dog wants to keep on improving (getting better) at his/her favourite things.	1	2	3	4	5
20.	My dog is interested in exploring places.	1	2	3	4	5
21.	My dog likes to do new and exciting things.	1	2	3	4	5

RSTPQ-D questionnaire and comparison with the original child version (Cooper t al., 2017)

	RSTPQ-D	RSTPQ-Child (Cooper et al., 2017)
FFFS:		
1.	My dog would be frozen to the spot if there was a dangerous animal in the house with him/her.	I would be frozen to the spot if there was a snake or spider in the bathroom with me.
2.	My dog would be frozen to the spot if he/she saw a large shadow when swimming.	I would be frozen to the spot if I saw a large shadow when swimming in the ocean.
3.	My dog would run away if he/she saw a dangerous animal.	I would run away if I saw a spider or snake.
4.	My dog would freeze if he/she thought a something was going to attack him/her.	I would freeze if I thought a bird was going to attack me.
5.	I would say my dog would freeze if he/she heard scary noises at night.	I would freeze if I heard strange noises when in bed at night time.
6.	My dog would run away from an animal if it was making her/him feel scared.	I would run away from an animal if it was making me feel scared.
7.	My dog would run upstairs if there was something scary downstairs.	I would run back upstairs if there were no lights on downstairs.
BIS:		
8.	My dog is careful when doing something that might hurt him/her.	I am careful when doing something that might hurt me.
9.	My dog would be careful when playing.	I would be careful when playing a game or sport.
10.	My dog would stop what he/she was doing if he/she thought there was physical danger or he/she might hurt him/herself.	I would stop what I was doing if I thought there was physical danger or I might hurt myself.
11.	My dog would stop what he/she was doing if he/she thought it was too risky to keep going.	I would stop what I was doing if I thought it was too risky to keep going.
12.	My dog worries about getting hurt.	I worry about what would happen if I was hurt.
13.	My dog would stop and think before going down a steep slope or sharp drop (where they would not be able to stop easily).	I would stop and think before going down a hill on a skateboard, rollerblades, bike etc.
14.	My dog appears to stop and think carefully before trying out for something.	I would think carefully about trying out for something (e.g., sports team, school captain etc.) in case I didn't

		make it in.
BAS:		
15.	My dog spends a lot of time trying to get better at things he/she likes doing (such as fetch/agility).	I am training to be better at sport/things I like doing.
16.	My dog works hard to do well at the things they like doing (like playing ‘find it’ or ‘fetch’).	I work hard to do well at the things I like doing.
17.	My dog likes to practice something he/she likes doing.	I like to practise something I like doing so I can get better.
18.	My dog puts in lots of effort to achieve a goal (or get what he/she wants).	I put in lots of effort to achieve a goal (or get where I want).
19.	My dog wants to keep on improving (getting better) at his/her favourite things.	I want to keep on improving (getting better) at my favourite things.
20.	My dog is interested in exploring places.	I am interested in exploring places.
21.	My dog likes to do new and exciting things.	I like to do new and exciting things.

Check-list of Behaviour Problems:

1. My dog barks, charges or lunges at people, dogs, other animals or certain objects

2. My dog growls or snarl (shows his/her teeth) at people, dogs, other animals or certain objects

3. My dog tries to bite people, dogs, other animals or certain objects

4. My dog snaps or bites people, dogs, other animals or certain objects

5. My dog urinates where he/she shouldn’t (e.g. in the house)

6. My dog defecates where he/she shouldn’t (e.g. in the house)

7. My dog shakes in the presence of certain people, animals, objects or situations (e.g. crowded places or loud noises)

8. My dog pants in the presence of certain people, animals, objects or situations (e.g. crowded places or loud noises)

9. My dog tries to avoid people, other animals, objects or situations (e.g. crowded places or loud noises)

10. My dog damages or destroys objects (e.g. chews shoes or carpets)

11. My dog digs holes in the garden, etc.

12. My dog shows other destructive behaviours