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Behavioural and physiological correlates of impulsivity in the domestic dog (*Canis familiaris*)

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ABSTRACT

Impulsivity is a trait related to inhibitory control which is expressed in a range of behaviours. Impulsive individuals show a decreased ability to tolerate delay of reinforcement, and more impulsive behaviour has been linked to decreased levels of serotonin and dopamine in a number of species. In domestic dogs, impulsivity is implicated in problem behaviours that result from a lack of self control, but currently there are no published studies that assess behavioural and physiological measures of impulsivity in relation to this trait. Impulsivity scores were calculated for 41 dogs using an owner-report assessment, the Dog Impulsivity Assessment Scale (DIAS). Twenty-three of these subjects completed an operant choice task based on a delayed reward paradigm, to assess their tolerance to delay of reinforcement. High Pressure Liquid Chromatography (HPLC) with Fluorometric Detection was used to detect levels of the metabolites of serotonin (5-HIAA) and dopamine (HVA) in the urine of 17 of the subjects. Higher impulsivity scores were found to be significantly correlated with more impulsive behaviour (reduced tolerance to delay of reinforcement) in the behaviour tests and lower levels of urinary 5-HIAA and 5-HIAA/HVA ratio. The results demonstrate convergent validity between impulsivity (as assessed by the DIAS) and behavioural and physiological parameters.

1. Introduction

In dogs, 'impulsivity' or 'impulse control' is often mentioned in the context of aggressive behaviour [1–4]. These studies describe 'impulsive aggression,' which has been defined as "aggressive behaviours occurring with reduced or absent warning signals" [2], and draw similarities with the human literature on impulse control [3,4], without prior consideration of whether the trait exists, or is expressed in the same way in dogs. They also fail to consider impulsivity in other, non aggressive contexts, and so do not provide an overall assessment of the underlying behavioural tendency. It is important to understand the wider role of impulsivity, in order to formulate more appropriate treatment plans for behaviour modification, which should target the underlying cause. Despite the implication that more impulsive individuals may be at increased risk of showing undesirable behaviours, there are no reported attempts to study impulsivity in controlled behaviour tests in domestic dogs.

There have been a number of studies on personality or temperament in dogs [5,6–12]. These studies attempt to assess behavioural styles (or traits) which are consistent over time, and are based on owner reporting or direct observations of behaviour. A psychometric tool based on owner report has recently been developed for the assessment of impulsivity in domestic dogs; the Dog Impulsivity Assessment Scale (DIAS, [13]). The DIAS provides a definition of impulsivity on two levels; firstly a narrow type of impulsivity which is related to the regulation of behaviour, and secondly, a broader form of impulsivity, which incorporates wider themes including aggression thresholds, response to novelty and general levels of responsiveness.

Studies on impulsivity in humans often rely on self rating scales specifically developed for assessing the impulsivity trait [14–16]. Such scales rely on the individual's ability to consider how they might feel or act in a given list of situations, and this provides an impression of their tendency towards impulsiveness. At a behavioural level, definitions of impulsiveness in the human literature tend to focus on two themes; firstly, the ability to tolerate delay of gratification, or reward [17] and secondly, the inability to delay or inhibit voluntary behaviour in response to stimuli [18]. Laboratory models of impulsivity in non human animals also tend to focus on response inhibition and delayed reward paradigms [19]. Response inhibition models assess the subject's ability to inhibit responding [20–22], and delayed reward models measure an animal's choice between a small, immediate reinforcer, and a large, delayed reinforcer, assessing 'impulsive choice', an index of impulsivity [23,24]. Van den Bergh et al. [25] investigated the relationship between response inhibition and delay aversion in rats, suggesting that response inhibition and delay aversion are independent measures of impulsivity, consistent with previous findings in humans [18].

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Research on the neurobiological basis of impulsivity has tended to focus on the serotonergic system [26–29]. In humans, lower levels of serotonin (5-HT) and its metabolite, 5-hydroxyindoleacetic acid (5-HIAA) have been found in impulsive violence compared to premeditated violence [27] and impulsive suicide attempters when compared to non-impulsive suicide attempters [30–32]. These results are reflected in findings with primates, where lower levels of CSF 5-HIAA have been found in relation to impulsive aggression [33], social impulsivity [34] and impulsive 'risk taking' behaviour [33,35,36]. Other studies demonstrating the link between 5-HT and impulsive behaviour involve pharmacological manipulations [23], and lesions of the 5-HT pathways [37,38].

The dopaminergic system is also suggested to play a role in impulsivity and delay of gratification [24,39,40], and some evidence suggests a potential role of noradrenergic systems in impulsivity [41,42]. The metabolites of serotonin (5-HIAA) and dopamine (HVA) have been found to be stable and trait like in their distribution in non human animals [33,43], indicating that they are reliable physiological markers. In addition, they have previously been detected in a range of biological substrates, including brain tissue [20], CSF [34] and urine [44]. Detection of these metabolites in urine provides a non-invasive alternative which is suitable for study on domestic dogs.

In dogs, reduced monoaminergic levels in cerebro-spinal fluid (CSF) may be associated with aggressive behaviour and impaired impulse control in aggressive contexts [1], and serotonin and dopamine related genes have been associated with aggression and impulsivity [4,45,46]. These findings support the idea that trait impulsivity in dogs has a similar biological basis to other species.

The aim of the study was to assess behavioural and physiological parameters of impulsivity in the domestic dog using a modified delayed reward paradigm and non-invasive assessment of urinary metabolites of serotonin and dopamine, and to investigate correlations with impulsivity assessed by the Dog Impulsivity Assessment Scale. It is predicted that dogs described as having a higher level of impulsivity in the DIAS, will demonstrate a lower tolerance to delay of reward, and have lower levels of the urinary metabolites of serotonin (5-HIAA) and dopamine (HVA), than individuals scored as being less impulsive.

2. Methods

2.1. Subjects

A convenience sample of 41 subjects was recruited through local dog training classes, university staff and students and dog owners that had previously volunteered their pets for research projects at the university. The subjects were volunteered by their owners, having given their informed consent to use their dogs in the study. The initial criterion for selection was that the dogs had sufficient motivation to work for dry dog kibble (i.e. would perform known obedience commands for dry food as a reward), and the dogs were reported to be in good physical health with no known signs of illness or injury. The owners were also asked to rate their dogs' previous experience of training on a scale of 0–2 (0 = little or no previous training, 1 = some to moderate previous training experience, 2 = lots of previous training experience).

The age of the recruited subjects (at time of commencing training) ranged from 7 to 133 months (mean 55.43 ± 37.27). The age at which subjects were acquired by the current owner ranged from 0 (owned since birth) to 72 months (mean 9.64 ± 17.26). The weight of subjects ranged from 5 to 33 kg, mean (17.50 ± 7.21). All combinations of sex and neuter status were represented (male neutered n = 14 (34.2%); male entire n = 3 (7.3%), female neutered n = 16 (39%); female entire n = 8 (19.5%)). The 41 dogs volunteered for the study included 14 crossbreeds and 27 pedigree dogs from 13 different breeds (1 Belgian Shepherd, 2 Border Terriers, 1 Cavalier King Charles Spaniel, 2 Cocker Spaniels, 6 Border Collies, 2 Springer Spaniels, 1 German Shepherd, 4 Labradors, 1 Miniature Poodle, 1 Staffordshire Bull Terrier, 4 German Spitz, 1 Spanish Water Dog and 1 West Highland White Terrier).

2.2. Impulsivity assessment

Owners were asked to complete a Dog Impulsivity Assessment Scale for their dogs [13]. This requires owners to rate their level of agreement with 18 statements concerning their perception of the behavioural tendencies of their dog, with individual item responses then scored on a 1–5 scale. Previous work [13] has identified that these ratings reduce to three factors with little cross-loading, reflecting relatively independent subscales that appear to contribute to owner perception of impulsivity. Therefore scores were calculated for the overall questionnaire score (OQS) and each of the three subscales: 'Behavioural Regulation' (containing nine items, e.g. 'dog does not think before it acts'; 'dog appears to have little control over how it responds', 'excitement can lead to fixed repetitive behaviour'); 'Aggression and Response to Novelty' (containing five items, e.g. 'dog becomes aggressive when excited', 'dog is not keen to go into new situations'); and 'Responsiveness' (containing four items, e.g. 'dog is easy to train', 'dog reacts very quickly').

2.3. Behavioural assessment

2.3.1. Test apparatus

The behaviour tests were conducted in the University's animal cognition laboratory. This laboratory space consisted of a single room divided into two smaller rooms by a partition wall (Fig. 1). This allows the subject to operate the chosen panel on an operant device in one room with the experimenter delivering the food from the other room, with the animal's behaviour video streamed to a monitor with the experimenter.

The operant device was based on a similar design used in previous domestic dog research [47]. The device consisted of a sprung hinged wooden panel that could be depressed with a dog's paw. Metal tubes, 15 mm diameter, allow the delivery of food pellets on to the wooden panel in response to the behaviour of the dog, with a Perspex cover allowing the device to be used with or without a food lure under the cover.

Three identically structured, but differently coloured, operant devices were used, so that they could be easily distinguished based on colour and luminance. The first, used as the training device, was white, with both a blue device and a yellow one used in the choice test. These colours were chosen as dogs have dichromatic vision [48] but a good ability to distinguish blue and yellow.

2.3.2. Training protocol

The training protocol for the delayed reward test is outlined in Table 1. The criterion to complete each phase was 10 panel presses within a five minute period. Subjects that did not complete training

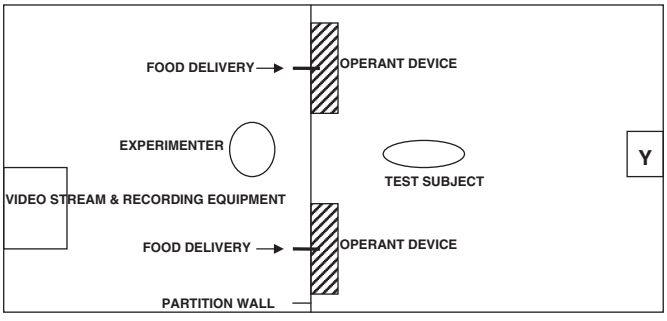

Fig. 1. Behavioural assessment.

Table 1
Training protocol for the delayed reward choice test.

	Aim	Device	Verbal + physical cues given by researcher	Food lure	Researcher in view
Training phase 1	Shape operant response (paw panel)	White centre position	Yes	Yes	Yes
Training phase 2	Remove cues given by researcher	White centre position	No	Yes	Yes
Training phase 3	Remove food lure	White centre position	No	No	Yes
Training phase 4	Perform operant behaviour in isolation	White centre position	No	No	No
Forced exposure	Expose to consequential rewards from two alternative devices	Two (blue and yellow) Left and right positions	No	No	Yes
Free choice exposure	Expose to free choice of two alternate devices	Two (blue and yellow) Left and right positions	No	No	No

phases 1–4 within nine 15 minute sessions were excluded from further testing and analysis. During training phase 4 it was also determined whether the subject would work in the room with the owner absent; for subjects that would not, the owner was asked to sit on a chair (position Y Fig. 1) and remain passive.

The aim of the forced exposure was to introduce the subjects to the two operant devices, and to the difference in timing and quantity of reward from each of the alternative devices. During this phase, the subjects were randomly allocated to a group, which determined position of the device and level of reward dispensed (immediate or delayed). Correct responses (pawing the panel to release food) on both devices were rewarded on a continuous reinforcement schedule. The small reward (one pellet of food) was dispensed immediately and the larger reward (three pellets of food) was dispensed after a 3 second delay. Dogs had to reach the same performance criteria on the device (without a food lure and without cues) to complete the forced exposure stage.

The aim of the choice exposure stage was for the dog to experience the contingent rewards from each of the two devices (small immediate or large delayed reward) in a free choice session. The choice exposure was carried out 7 days following the forced exposure. During this session, the dog had a free choice of the two devices. Each press on the panel of the small-immediate reward device was reinforced with one food pellet immediately after the press. Each panel press of the large-delayed reward device was reinforced with three food pellets after a delay. This delay was 3 s at the beginning of the 15 minute session, but increased by 1 s every other time the dog pressed the large-delayed reward panel. If the subject removed itself from the large-delayed reward device during the delay (before the food was dispensed), and pressed the alternative panel (small-immediate device), this cancelled the choice of the large-delayed device and no food was dispensed from this device. Instead, the subject was reinforced for the small-immediate choice as usual. The choice to move away from the large-delayed reward device to the small-immediate reward device did not reset the delay for the next press of the delayed panel; the time delay continued to increase from the delay that had been reached on the previous press of that panel. The onset of the delay coincided with the first press on the panel; any additional presses between the first press and the delivery of food had no effect on the delay or food delivery. The purpose of including the choice exposure stage was to allow the subjects experience of free choice of both devices and their consequential rewards. No data was collected during this phase.

2.3.3. Delayed reward choice test

The delayed reward choice test was carried out 7 days following the choice exposure and followed the same protocol. Data was collected during this testing phase. The subject was directed into the test area and was left, facing away from the two devices, for a 15 minute period with a free choice of operating both devices. The subject's behaviour was observed remotely and recorded during this time. The consequences of pressing either device were the same as in the choice exposure.

Nine parameters were recorded from the delayed reward choice task (Table 2). In line with the work of Wolff and Leander [23], the maximum delay reached on the large-delayed device at the end of the 15 minute choice test (MaxD) was considered the primary measure of 'impulsive choice', where a higher maximum delay is considered less impulsive (more self controlled) and a lower maximum delay is considered more impulsive.

2.4. Repeat testing on the delayed reward choice test

The delayed reward choice test was repeated on a further two occasions for 9 of the 24 subjects to assess reliability. These further two tests were carried out a minimum of 6 weeks after completion of the first test and were 1 week apart.

2.5. Assessment of urinary metabolites of serotonin and dopamine

Urine samples were collected from 30 of the 41 recruited subjects between 9 am and 6 pm on days when the subjects were on site for the behaviour tests. Samples were sealed with paraffin oil, before acidification and freezing at −70 °C [49] to allow later analysis. A second urine sample was collected from 18 of the subjects a minimum of 48 h after the first sample.

HPLC with fluorometric detection was used to detect levels of 5-HIAA and HVA in the samples [50]. The metabolite peaks for 5-HIAA and HVA on the chromatogram were identified by their retention times. In order to confirm the retention times of each metabolite, standard solutions containing known concentrations of the metabolites 5-HIAA and HVA were run before and after each sample. Calibration curves based on a set of six samples were constructed to determine the concentration of the metabolites in the samples.

The concentration of creatinine (CR) in each sample was determined using the Jaffe reaction [51] in order to account for variability in concentration of the urine samples. 5-HIAA and HVA concentrations could then be expressed as a ratio of metabolite creatinine.

Table 2
The eight parameters recorded in 15 minute delayed reward choice test.

PI	Number of presses on small immediate panel that were rewarded
PDR	Number of presses on large delayed panel that were rewarded
PDNR	Number of presses on large delayed panel that were not rewarded (i.e. the subject walked away before the reward was delivered and operated the alternative device).
Tpress	Total number of presses on devices (excluding extra presses between first press and delivery of food each time a device was chosen) i.e. Tpress = PI + PDR + PDNR
Food	Number of food pellets gained in the 15 minute period
MaxD	Maximum delay reached on large delayed device
FP	Device which was pressed first
Switches	Number of switches between the two devices
ExP	Extra presses between first press and food delivery on delayed reward device (average presses per second).

2.6. Statistical analysis (SPSS 14.0)

Data were assessed for normality (Kolmogorov–Smirnov test), and when they deviated significantly from normality, equivalent non-parametric tests were used for analysis. Pairwise comparisons were made within the demographic variables, urinary metabolite levels, Overall Questionnaire Score (OQS), and the three subscales for subjects that completed the training and testing and those that did not. A Mann–Whitney *U* test was used to evaluate whether presence of the owner during the behaviour tests had an effect on the primary measure of performance in the delayed reward choice task (MaxD) and whether this factor was associated with different scores on the DIAS. Correlations were used to consider the relationship between behavioural performance measures (MaxD value from the first exposure to this test) and questionnaire measures. A Pearson's product–moment correlation was used to consider the correlation between repeat performances in the delayed reward choice test.

Pearson's product–moment correlations and paired t-tests were used to evaluate the consistency of metabolite levels (5-HIAA and HVA) corrected against creatinine levels in repeat urine samples. Similar correlations were also used to evaluate the relationship between corrected metabolite levels as well as their ratio and measures of impulsivity from the DIAS and MaxD. Average values for the metabolite levels of 5-HIAA and HVA were used for subjects with repeat samples. In order to evaluate if the ratio of levels of serotonin to dopamine metabolite added significantly to the relationships with the questionnaire scores beyond that based on the serotonin metabolite alone, the effect of partialling out the ratio on the relationship with 5-HIAA was evaluated with Pearson's correlations.

3. Results

3.1. Training performance and relationship with demographic variables

58.5% (n = 24) of the recruited subjects successfully completed the training and the behaviour test. Reasons for failure among the other 17 subjects included: fearful or anxious behaviour towards the environment or operant device (n = 6); owner opted out of study (n = 4); subject would not work without social contact (n = 3); failure to complete training phase 1 within time limit specified (n = 2); subject illness or injury (n = 2). The dogs that completed training did not differ significantly from those who failed to complete training in age ($t(39) = -0.910$, $p = 0.368$), weight ($t(39) = 1.107$, $p = 0.275$), age acquired ($Z = -0.854$, $n = 35$ $p = 0.393$) or gender ($\chi^2(1) = 2.497$, $p = 0.476$). There was an effect of previous training on test completion: subjects reported as having a high level of previous training were more likely to complete the training ($\chi^2(1) = 4.571$, $p = 0.033$). There was no significant difference in any of the DIAS scores (OQS and the three subscales) between the population of subjects that completed the training and those that did not complete (Independent samples' *t*-test $p > 0.05$).

3.2. Delayed reward choice test

It was hypothesised that MaxD (the maximum delay reached on the delayed reward device in the choice test) was the ultimate measure of impulsivity within this test, being the derivative of several performance factors that might reflect the level of behavioural impulsivity within the test, such as tolerance of delayed reward gratification and stimulus directed behavioural activity. It has also been used as the primary outcome variable by other authors using a similar paradigm in other species [23]. Indeed MaxD was highly correlated with five of the other measures of performance within the task (Table 3). As expected, subjects who opted for the immediate reward more, chose the delayed reward less, and so reached a lower delay on the delayed reward in the test period.

The maximum delay reached on the delayed reward device (MaxD) ranged from 7 to 27 seconds (s), mean 15.86 s ± 5.130 s (n = 22), with two subjects not pressing the delayed reward panel at all. These subjects were excluded from further analysis, since they did not indicate sampling of the available test choice.

The correlation between MaxD and impulsivity as assessed by the overall questionnaire score was significant and inverse ($r = -0.646$, $p < 0.001$) (Fig. 2). A relationship was also identified between MaxD and the 'Behavioural Regulation' subscale, ($r = -0.684$, $p < 0.001$) (Fig. 3). No significant correlations were found between MaxD and the 'Aggression and Response to Novelty' ($r = -0.138$, $p = 0.541$) or 'Responsiveness' ($r = 0.341$, $p = 0.121$) subscales.

Table 3
Spearman's correlations. Parameters recorded from the delayed reward choice task.

	PI	PDR	PDNR	TPress	Food	MaxD	Switches
PDR	r = −0.911 p < 0.001** n = 24						
PDNR	r = −0.052 p = 0.819 n = 22	r = −0.030 p = 0.894 n = 22					
Tpress	r = 0.983 p < 0.001** n = 24	r = −0.849 p < 0.001** n = 24	r = −0.043 p = 0.849 n = 22				
Food	r = 0.936 p < 0.001** n = 24	r = −0.742 p < 0.001** n = 24	r = −0.146 p = 0.518 n = 22	r = 0.974 p < 0.001** n = 24			
MaxD	r = −0.892 p < 0.001** n = 22	r = 0.998 p < 0.001** n = 22	r = −0.109 p = 0.646 n = 22	r = −0.808 p < 0.001** n = 22	r = −0.679 p = 0.001** n = 22		
Switches	r = 0.201 p = 0.346 n = 24	r = −0.104 p = 0.627 n = 24	r = 0.555 p = 0.007** n = 22	r = 0.206 p = 0.335 n = 24	r = 0.178 p = 0.404 n = 24	r = −0.385 p = 0.077 n = 22	
PRate	r = 0.332 p = 0.131 n = 22	r = −0.571 p = 0.006** n = 22	r = 0.283 p = 0.226 n = 22	r = 0.284 p = 0.200 n = 22	r = 0.172 p = 0.445 n = 22	r = −0.561 p = 0.007** n = 22	r = 0.169 p = 0.453 n = 22

PI = presses on small, immediate device, PDR = presses on delayed reward device that were rewarded, PDNR = presses on delayed reward device that were not rewarded (i.e. subject walked away before food was dispensed), TPress = total presses on the devices, Food = number of food pellets obtained, MaxD = maximum delay reached on delayed reward device, Prate = rate of presses on the delayed reward device food delivery (average presses per second).
** $p < 0.01$.

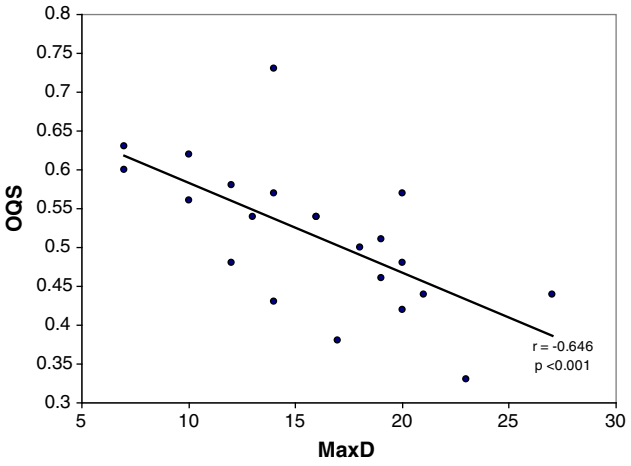

Fig. 2. Pearson's correlation. MaxD and overall questionnaire score.

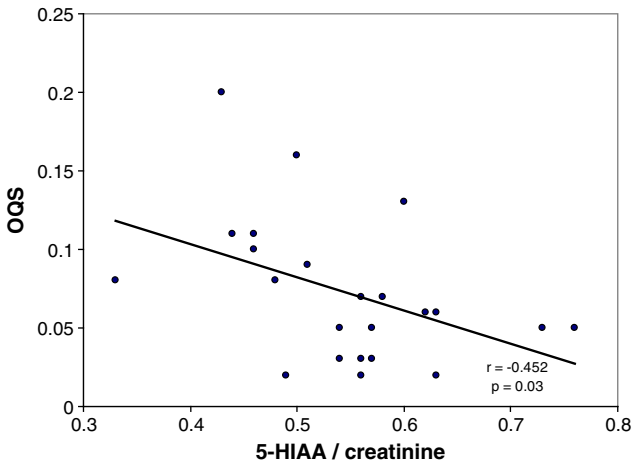

Fig. 4. Pearson's correlation. Impulsivity (Overall Questionnaire Score) and 5-HIAA/creatinine.

There was no significant difference between MaxD, OQS, Behavioural Regulation, Aggression and Response to Novelty, and Responsiveness scores of subjects that completed the tests with the owner absent or owner present (Mann Whitney U, $p>0.05$).

The extra presses on the delayed reward device were counted and average rate of pressing on this device was calculated (from first press to delivery of food on each of the delay levels). The average rate of pressing was higher in subjects who reached a lower MaxD ($r=-0.561$, $p=0.007$), and who opted for the delayed choice less ($r=-0.571$, $p=006$). The average rate of pressing and impulsivity as assessed by the overall questionnaire score was significant and inverse ($r=-0.447$, $p=0.037$), as was the average rate of pressing and the 'Behavioural Regulation' subscale, ($r=-0.446$, $p=0.038$).

The number of presses on the large, delayed reward panel that was not rewarded (i.e. the subject walked away and pressed the alternative panel) correlated significantly with the number of switches between the two devices ($r=0.555$, $p<0.05$). These subjects showed a higher frequency of switching between the two devices as they often opted out of waiting for the large delayed reward to be delivered.

Test–retest reliability was good, since there was a significant correlation in performance in the delayed reward task over repeated tests. The maximum delay reached (MaxD) in the original test strongly correlated with the same measure in repeat test 1 ($r=0.705$, $p=0.034$) and repeat test 2 ($r=0.688$, $p=0.041$). Correlation between MaxD scores was highest for repeat test 1 versus repeat test 2 ($r=0.975$, $p=0.001$).

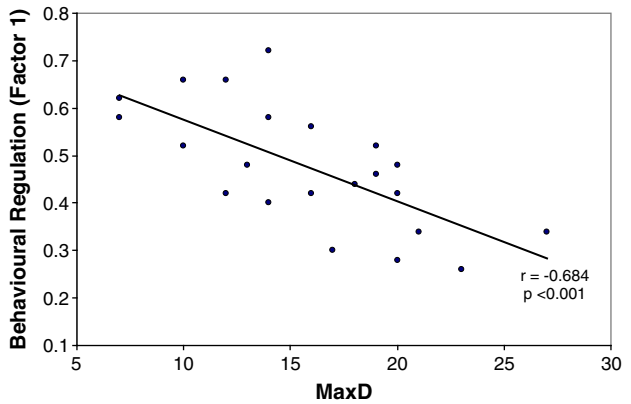

Fig. 3. Pearson's correlation. MaxD and factor 1 (Behavioural Regulation).

3.3. Urinary metabolites

Thirty three of the 48 urine samples yielded viable HPLC results for both 5-HIAA and HVA. The remaining 15 urine samples did not produce peaks on the chromatogram that could be reliably identified. The 33 samples represented 23 subjects, 13 of which had results from a single urine sample and 10 from two urine samples. Of these 23 dogs, all had completed the DIAS and 17 had completed the laboratory behaviour tests. The levels of 5-HIAA/creatinine detected ranged from 0.02 to 0.2 mmol/L, mean 0.07 (± 0.05). HVA/creatinine ranged from 1.25 to 12.4, mean 3.96 (± 2.68).

Measures appeared stable with no significant difference in the levels of 5-HIAA/creatinine ($t(9)=-0.11$, $p=0.92$), HVA/creatinine ($t(9)=0.45$, $p=0.66$) and the 5-HIAA/creatinine:HVA/creatinine ratio ($t(9)=-0.087$, $p=0.93$) for subjects with duplicate samples ($n=10$). In addition, the correlation between the two repeat samples for the 5-HIAA/HVA ratio was significant ($r=0.689$, $p=0.027$).

OQS correlated significantly and inversely with both 5-HIAA/creatinine ratio ($r=-0.452$, $p=0.03$) and the 5-HIAA/creatinine:HVA/creatinine ratio ($r=-0.484$, $p=0.02$) (Figs. 4 and 5). Partialling out the ratio of 5-HIAA:HVA resulted in the relationship with 5-HIAA becoming non-significant ($r=-0.229$, $p=0.3$), indicating the ratio of 5-HIAA:HVA was the most useful correlate. A similar negative relationship was also found between 'Behavioural Regulation' score and the 5-HIAA/creatinine:HVA/creatinine ratio ($r=-0.435$,

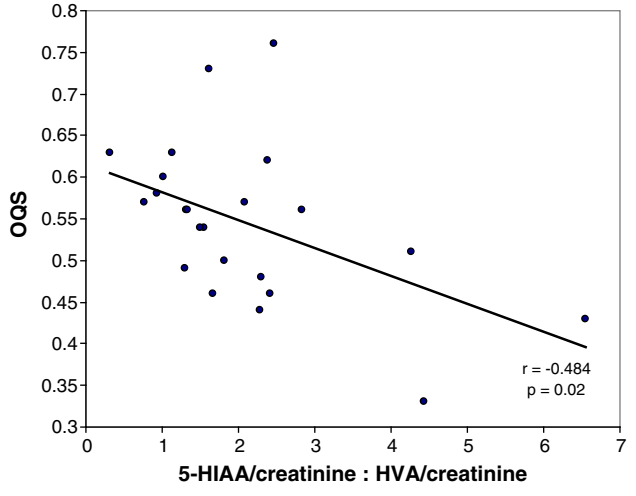

Fig. 5. Pearson's correlation. Impulsivity (Overall Questionnaire Score) and 5-HIAA/creatinine:HVA/creatinine.

$p = 0.04$). No further correlations between the urinary metabolites and measures from the questionnaire were found.

No significant correlations were found between the urinary metabolites and the primary measure of impulsivity from the delayed reward task (MaxD and 5-HIAA/CR:HVA/CR ratio: Pearson's $r = 0.393$, $p = 0.119$).

4. Discussion

The aim of this study was to assess behavioural and physiological parameters of impulsivity in the domestic dog. A major finding is that performance of dogs in a delayed reward choice task was related to owners' subjective rating of impulsivity, using the DIAS scale. Dogs with higher DIAS scores tolerate lower maximum delays, preferring smaller, more immediate rewards. This is supported by previous studies which relate higher levels of impulsivity to reduced ability to tolerate delay of reinforcement [23,26,52].

It was also found that dogs with a higher average rate of paw pressing during the delay period scored higher on the DIAS, and reached lower overall delays on the delayed reward device. This demonstrates the relationship between increased impulsivity and reduced behavioural inhibition. Although response inhibition is generally reported to be a separate element of impulsive behaviour to delay of reinforcement, studies in other species show that the two are related [18,25].

Repeated tests demonstrate strong correlations between the original and two repeats, supporting its reliability and temporal stability. A slight drift towards a more impulsive choice after repeated exposure was observed, which could be a consequence of learning, although no significant difference was found. This determination of reliability provides an advance on the report of Wolff and Leander [23], who did not report on the reliability of the delayed reward test used.

It is perhaps surprising that the dogs' level of impulsivity was not found to be related to completion/non completion of training, as reduced attention span is often discussed in relation to impulsivity, particularly in the human literature on ADHD [53]. It has been suggested that this is also the case in domestic dogs [54]. However, the dogs' previous training history, which may include experience in problem solving, was found to be more important in their ability to complete the training. It may be that the lack of training in some subjects was more a function of owner choice than trainability per se, so it is not possible to comment further on the relationship between impulsivity and attention span in dogs. This also highlights for the need in future research using the delayed reward paradigm for subjects to have a certain level of prior training experience.

Another major finding is that the level of serotonin and dopamine metabolites in the dogs' urine was related to the owners' subjective rating of impulsivity using the DIAS scale. The serotonergic and dopaminergic systems have been implicated in impulsive behaviour; serotonin is suggested to relate to behavioural inhibition, and dopamine to behavioural activation, response thresholds and sensitivity to reward [28,55,56]. The inverse relationship between these neurotransmitter systems and impulsivity has been demonstrated in both humans e.g. [57] and non-human animals, e.g. [20,34]. No clear relationship was identified between the delayed reward choice test and urinary metabolite levels. This lack of power may be attributed to small sample sizes. Alternatively, this finding may suggest that tolerance to delay of reinforcement is only one aspect of impulsivity whilst the serotonergic and dopaminergic systems have a much broader effect on behaviour (mediating interactions between behavioural inhibition and behavioural activation). Yet even if this idea is correct, a relationship between the metabolite levels and performance in the delayed reward task might be expected, as serotonin raises behavioural thresholds, and this would be reflected in their performance in such a task. It is important to note however, that whilst there is a long history of the measurement of neurotransmitters and their metabolites in blood, CSF and urine in a range of species [1,30,43,49], the potential influence of the renal system on CNS levels remains unclear. Additional limitations in this study exist due to incomplete data resulting from unidentifiable chromatogram peaks following HPLC analysis.

The relationships identified between the DIAS and both behavioural and physiological parameters provide validation of the scale. This study demonstrates a level of rigour that has not previously been attempted in the assessment of behavioural traits in companion animals. As such, it closes the gap between traditional studies on dog behaviour and the expanding literature on animal models of personality traits. The trait appears to have a similar physiological basis to humans and other non human animals, being influenced by interactions between the serotonergic and dopaminergic systems. The DIAS allows the relatively rapid assessment of this trait in dogs in a range of contexts. This is important because it gives an indication of whether impulsivity is an underlying factor in a range of behaviour disorders, and may be of particular relevance in cases where a clinician is considering pharmacological intervention in addition to behavioural therapy. The DIAS has a range of potential applications, including in the prevention and treatment of behavioural problems, and the prediction of success in working dog and assistance animal programmes worldwide. These results also expand the opportunity for the study of disorders of human personality relating to impulsivity in the dog, potentially using spontaneous models which may have greater external validity than the more environmentally restricted or artificially induced models possible in the laboratory.

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