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Do dogs experience frustration? New contributions on successive negative contrast in domestic dogs (*Canis familiaris*)

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ABSTRACT

An unexpected change in reward quantity or quality frequently elicits a sharp decrease of responses as well as a negative emotional state. This phenomenon is called successive negative contrast (SNC) and, although it has been observed in numerous mammals, results in dogs have been inconsistent. The aim of this study was to evaluate SNC in dogs, comparing the effects of rewards of different qualities in a non-social task carried out in the dogs' usual environment. Dogs were separated into two experimental groups that experienced a downshift from a high quality reward (liver or sausage) to a low quality one (dry food), as well as a control group that always received dry food. The task involved a dog toy with bone shaped pieces that had to be removed to get the food hidden underneath. When the reward changed from liver to dry food, dogs picked up significantly fewer bones than the control group. However, this effect was not observed with sausage. Results show SNC in dogs in a non-social task carried out in their home environment. Additionally, the importance of the discrepancy in the hedonic value of the rewards is highlighted.

1. Introduction

Successive negative contrast (SNC) is a phenomenon that occurs when there is an unexpected change from a high value incentive to one of lower quantity or quality (e.g., Papini et al., 1988). This devaluation of the incentive elicits a reduction of consummatory or instrumental behavior that is not observed in unshifted controls which always received the low value reward (Flaherty et al., 1996). Additionally, Amsel (1992) described that animals that undergo this surprising downshift, experience an aversive emotional state known as frustration. While this direct negative experience has been named primary frustration, stimuli paired with such a state elicit a conditioned expectancy in later trials, called secondary frustration. These emotional responses are similar to the anxiety induced by the presentation of more conventional aversive stimuli (Papini and Dudley, 1997). Furthermore, some authors suggest there is a parallel in the mechanisms underlying physical pain and psychological pain induced by reward loss (for a review, see Papini et al., 2006).

So far, SNC has been observed in numerous mammal species such as marsupials (Papini et al., 1988), rats (e.g., Cuenya et al., 2012), mice (Mustaca et al., 2000), mongolian gerbils (Pérez-Acosta et al., 2016), sheep (Catanese et al., 2011), fallow deer (Bergvall et al., 2007), monkeys (Tinklepaugh, 1928), chimpanzees (Cowles and Nissen, 1937) and humans (e.g., Kobre and Lipsitt, 1972; Cuenya et al., 2013). Conversely, this phenomenon has not been found in nonmammalian vertebrates such as goldfish (Couvillon and Bitterman, 1985), turtles (Papini and Ishida, 1994), pigeons (Papini, 1997) and toads (Muzio et al., 2011). In particular, nonmammalian vertebrates show a reversed SNC effect, as they do discriminate different reward magnitudes during the preshift phase (i.e., before the change in the incentive's value), but the downshift is followed by a gradual change of behavior or no change at all (e.g., Muzio et al., 2011). Therefore, some authors suggest that the brain circuits underlying secondary frustration, as it is elicited by SNC paradigms, may be unique to mammals (Papini et al., 2006). However, there are some exceptions of nonmammals in which SNC has been found, including birds (starlings in Freidin et al., 2009) and insects such as honey bees (e.g. Wiegmann and Smith, 2009) and bumble bees (Waldron et al., 2005).

Regarding domestic dogs, the literature on SNC is scarce and results are still inconsistent. Bentosela et al. (2009) evaluated this phenomenon on a social task carried out in the dogs' home. To this end, they were reinforced each time they gazed at a person's face to ask for food,

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and results indicated that downshifted dogs gazed less during the postshift phase than those which always received the low quality reward. Later on, Riemer et al. (2016) carried out the same protocol in both family and shelter dogs, analyzing the effects in a within as well as a between subject design. However, they found no SNC effect in either group. They conclude that, as SNC is usually studied within laboratory conditions, it may not be a phenomenon robust enough to be easily reproduced in other environmental contexts and populations. However, the dissimilar results found in these studies may have been caused by variations in their methodology. For example, while Bentosela et al. (2009) used pieces of homemade cooked liver as high quality rewards, Riemer et al. (2016) used pieces of sausage as well as a verbal reward ('Good') prior to giving the food. Additionally, Pongrácz et al. (2013) studied the effect of different food rewards in a pointing task. On the first session dogs received either carrot or sausage, and in the second one all dogs received dry food. Correct choices and response latencies did not differ between phases in the sausage group (negative contrast group). The authors suggest this lack of contrast effect may be due to the interaction with the experimenter, as dogs may be less sensitive to food quality in cooperative situations. Therefore, social factors may attenuate SNC in dogs, as the interaction with a person could act as an incentive in itself, given the strong bond between humans and dogs. Furthermore, Riemer et al. (2018) examined the effects of changes of quality and quantity of the reward on dogs' running speed in a non-social runway task. Running speed was affected by changes in reward quality but not quantity. In particular, results indicate that dogs ran faster in the food quality condition, but they continued to do so after the downshift from high quality to low quality reward. Therefore, SNC was not observed in this task and authors highlight the limited evidence of the occurrence of this effect in this species.

Taking these results into account, the aim of study 1 A was to assess SNC in domestic dogs employing a non-social task, carried out in the dogs' usual environment and including both types of high quality rewards featured in previous works (liver and sausage). Meanwhile, the low quality reward was the commercial dry food each dog usually ate. These rewards were selected because in Bentosela et al. (2009) it was observed that liver was a preferred food, while the usual dry food the dogs consumed was the least preferred. Additionally, sausage was included as it was used as a high quality reward in Pongrácz et al. (2013); Riemer et al. (2016) and Riemer et al. (2018). Considering prior literature in mammals as well as the results of Bentosela et al. (2009), it was predicted that dogs in the liver group would experience SNC after being downshifted to dry food. Predictions for the sausage group were unclear, as previous studies using this reward did not find SNC in dogs.

Moreover, the comparison between two high quality rewards allows to assess the effect of different incentive values on the appearance of SNC. In line with this, study 1B aimed to evaluate dogs' preference for liver or sausage.

2. Method

2.1. Ethical statement

This study was carried out in compliance with the current Argentine law of animal protection (Law 14.346) and was developed with the approval of the CICUAL (Institutional Commission for the Care and Use of Laboratory Animals) from the Medical Research Institute IDIM CONICET (Res. N° 080 - 18). All owners expressed their consent for the participation of their dogs in this study.

2.2. Study 1A

2.2.1. Subjects

We assessed 46 domestic dogs. However, 19 had to be eliminated from the study as they were not interested in the task or were fearful of the experimenters. Hence, the final sample consisted of 27 dogs. All of them were healthy adults, ranging from 8 months to 9 years old (mean age = 4.7, SD ± 2.7), 14 males and 13 females. The sample included several dog breeds (three Labrador Retriever, three Beagle, two Boxer, two German Shepherd and one Chow Chow, Dachshund, Pit Bull, Rottweiler, Samoyed, Schnauzer, Shiba Inu) and 10 dogs of mixed breed. All dogs were not fed for 6 h prior to the test, while water was available ad libitum.

Fig. 1. Experimental setting.

2.2.2. Apparatus

The apparatuses used were two Nina Ottosson© Dog Magic interactive toys, which the dogs had not seen before. Each toy consisted of a round base of 36 cm in diameter, with nine bone-shaped depressions containing nine plastic removable bones (eight arranged in a circle, and the ninth located in the middle). All bones had a small hole to release the smell of food hidden underneath. One toy was smeared with either liver or sausage (according to the experimental group), while the other was smeared with the dry food the dog usually ate soaked in water, in order to distribute the smell evenly. The toy was placed on a small carpet to prevent it from slipping around. A perimeter of 1 m was marked around the toy, to later determine the dogs' proximity (see Fig. 1). A helper filmed the situation with a Sony DCR-SR 88 video camera for further analysis of behaviors.

2.2.3. Procedure

Dogs were tested in a quiet familiar room within their homes, which they were allowed to freely explore for five minutes in order to get used to the situation. After that, an experimenter came in carrying the baited toy and put it down, saying "now" to signal the start of the trial, and then leaving. For the first trial the toy had 3 bones partially removed, in order to facilitate the resolution of the task. Dogs were free to interact with the toy, and once the trial ended the experimenter came back and took the toy to another room to refill it. This was repeated for all trials.

Dogs were randomly assigned to three groups: Experimental liver group (EL, N = 9), Experimental sausage group (ES, N = 9) and Control (C, N = 9). EL and ES groups received a preshift phase of 4 trials of high quality reward (liver or sausage depending on the group) and, after a 25 min interval, a postshift phase of 3 trials of low quality reward (dry food). This interval was included to avoid an effect of sensorial carry-over across the phases. Finally, after 1 min, there was a reshift phase of 1 trial with the high quality reward (liver or sausage), in order to control for satiety or fatigue on the behavior. Meanwhile, C group received dry food for all trials.

Trial duration for first and third phases was either 3 min or until the dog removed all bones. In the second phase, trials lasted 3 min regardless of the number of bones removed. Inter trial interval was of 1 min, in which the toy was taken away and refilled in another room out of the dog's view. Therefore, in the room there were the dog and the helper holding the camera, who stood 3 m from the setting and ignored the animal.

2.2.4. Data analysis

Measures included the number of picked up bones and the time (s) the dog stayed close (less than 1 m) to the toy in each trial.

The number of picked up bones was scored live after each trial by both the experimenter and the helper. Agreement between them was perfect as the measure was unequivocal. Time spent close to the toy was coded from the video, and a second experimenter measured 30% of the videos, with a high interobserver reliability (Cronbach's alpha > 0.96). Given the duration varied across trials, rates were calculated dividing the time the animal spent close to the apparatus by the total time of the trial.

As the measure 'number of picked up bones' was not normally distributed (Kolmogorov Smirnov, $p < 0.05$), non-parametric statistics were used in the analysis. Kruskal–Wallis test was used to compare the effect of group on the number of bones the dog picked up in each trial. As there were effects of group, pairwise comparisons were carried out with the Mann–Whitney U test, with Bonferroni corrections for multiple comparisons. Friedman test was used to analyze trial effects on the pre and postshift phases.

Regarding the time spent near to the apparatus, Kruskal–Wallis test was used to compare the effect of group on each trial of the preshift and reshift phases. Friedman test was used to analyze trial effects on the preshift phase. Given the trials of the postshift phase followed a normal distribution, a repeated measures ANOVA with trials as a within subject factor and group as a between subject factor. Bonferroni pairwise comparisons were used. Effects of sex and age were analyzed using Mann–Whitney U and Spearman's rank correlation coefficient, respectively. All tests were two tailed ($\alpha = 0.05$). The data were analyzed with the statistics program SPSS (v20).

Videos of trials 1 and 2 of one dog from the ES group were lost due to a camera malfunction, so they were excluded from the analysis of time spent near the apparatus (number of picked up bones had been scored live during the test).

3. Results & discussion

3.1. Number of picked up bones

Fig. 2 shows the mean number of picked up bones across trials. During the preshift phase there was a significant trial effect ($X^2 = 14.48, p = 0.002$), but the group effect was non-significant for all trials (trial 1: H (2) = 2.89, $p = 0.23$; trial 2: H (2) = 1.73, $p = 0.42$; trial 3: H (2) = 0.08, $p = 0.96$; trial 4: H (2) = 2.00, $p = 0.36$).

Regarding the postshift phase, there was no significant trial effect (X^2 (2) = 0.11, $p = 0.94$). However, results show a significant group effect on all trials of this phase (trial 5: H (2) = 12.52, $p = 0.002$; trial 6: H (2) = 14.44, $p = 0.001$; trial 7: H (2) = 10.41, $p = 0.005$). Mann–Whitney U comparisons with Bonferroni correction ($p < 0.016$) indicate that the number of bones picked up by the EL group was significantly different from the C group for all postshift trials (trial 5: $U = 6$, $p = 0.001$; trial 6: $U = 4.5$, $p < 0.001$; trial 7: $U = 10$, $p = 0.003$). No significant differences following Bonferroni correction were found between ES and C groups (trial 5: $U = 21$, $p = 0.04$; trial 6: $U = 22.5$, $p = 0.02$; trial 7: $U = 31$, $p = 0.24$), nor between EL and EC (trial 5: $U = 17$, $p = 0.03$; trial 6: $U = 15$, $p = 0.02$; trial 7: $U = 17.5$, $p = 0.03$).

During the reshift phase there was no significant group effect (H (2) = 4.15, $p = 0.12$).

Table 1
Mean (in bold) and standard deviation of the rate of time spent near the apparatus.

Group		Trials 1	2	3	4	5	6	7	8
EL	M	**0,91**	**1,00**	**0,93**	**1,00**	**0,49**	**0,39**	**0,32**	**1,00**
	SD	0,22	0,01	0,21	0,00	0,25	0,29	0,28	0,00
ES	M	**0,90**	**0,99**	**0,99**	**1,00**	**0,79**	**0,54**	**0,62**	**1,00**
	SD	0,19	0,02	0,03	0,00	0,21	0,34	0,34	0,00
C	M	**0,89**	**0,87**	**0,96**	**1,00**	**0,75**	**0,66**	**0,57**	**0,85**
	SD	0,18	0,20	0,11	0,00	0,19	0,18	0,21	0,30

Note: EL: experimental liver group, ES: experimental sausage group, C: control group.

3.2. Time spent near the apparatus

Regarding time spent in proximity to the apparatus (see Table 1), during the preshift phase there was a significant effect of trial (X^2 (3) = 9.26, $p = 0.02$), but not of group for any trial (trial 1: H (2) = 0.46, $p = 0.79$; trial 2: H (2) = 2.89, $p = 0.23$; trial 3: H (2) = 1.66, $p = 0.53$; trial 4: H (2) = 0, $p = 1$).

During the postshift phase there were significant effects of trial (F (248) = 7.87, $p = 0.001$) and group (F (224) = 4.14, $p = 0.028$). However, Bonferroni's post hoc comparisons only showed a tendency towards significance in EL vs C ($p = 0.054$) as well as EL vs ES ($p = 0.066$), but not for ES vs C ($p = 1$). Trial x group interaction effect was not significant (F (448) = 0.78, $p = 0.54$).

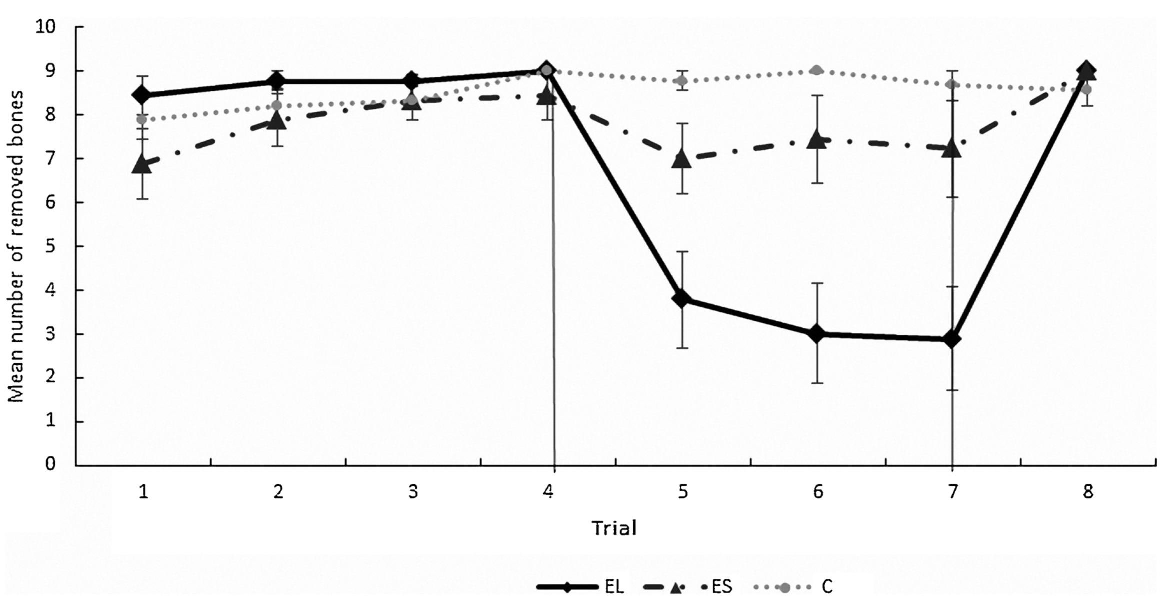

Fig. 2. Number of removed bones (mean ± SEM) across trials in the experimental liver group (EL), experimental sausage group (ES) and control group (C). Lines indicate the different phases (preshift, postshift, reshift).

During the reshift phase there was no significant group effect (H (2) = 4.15, $p = 0.12$).

Finally, there were no significant effects of sex ($ps > 0.24$) nor age ($ps > 0.05$) on either variable.

These results show that dogs picked up significantly fewer bones when the reward was downshifted from liver to dry food in comparison to control dogs which always received dry food. Moreover, EL dogs exhibited a tendency to spend less time close to the toy during the postshift phase than the control group. These findings suggest the presence of SNC in the EL group but not in the ES one. One possible explanation for this difference is that liver may be a more preferred food than sausage and thus there may be a greater incentive value discrepancy between it and the dry food received during the postshift phase. Taking this into account, we carried out Study 1B in order to evaluate dogs' preference for both rewards (liver vs sausage).

4. Study 1B

4.1. Subjects

We assessed a new sample, consisting of 11 domestic dogs. However, two had to be eliminated from the study as they exhibited a side preference (they chose the same side for at least four consecutive trials out of the last five of the test). Hence, the final sample consisted of 9 dogs. All of them were healthy adults, ranging from 1 to 10 years old (mean age = 7.3, SD ± 2.7), 2 males and 7 females. The sample included one Poodle, one German Shepherd and 7 mixed breed dogs. All dogs were not fed for 6 h prior to the test, while water was available ad libitum.

4.2. Apparatus

Two identical 22 x 18 cm trays, one always employed for each reward (liver or sausage), were used to show the food to the dogs. The rewards were always pieces of liver and sausage of a similar size (see Fig. 3).

4.3. Procedure

The experimenter placed a single piece of food on each tray with a different spoon for each reward, to avoid touching them with her hands and mixing the smells. The dog was held on a leash by a handler at 50 cm from the E, so that they were able to smell the food but not consume it.

First, there were two consecutive pre training trials in which dogs were able to eat from each tray in order to get familiarized with the two available foods. The starting side was counterbalanced across trials.

Immediately thereafter, the test began. For each trial, the E brought one tray in each hand, showing them side by side to the dog and allowing it to smell both of them consecutively. The side in which each reward was located and the tray that was smelt first were counterbalanced across trials, so the same side was not repeated more than two consecutive trials. During this part, the handler held the dog to prevent it from picking up the food. After the dog had smelt each tray, the E took a step back and separated the trays approximately 1 m (spreading her arms as much as possible), and the dog was allowed to choose. Once the dog selected one tray (touching it or coming within 10 cm from it), it was allowed to eat that reward while the other tray was moved away, so the non selected one could not be eaten. There were 10 trials with an inter trial interval of 10 s.

Fig. 3. Pieces of both high quality rewards used during these studies (liver and sausage).

4.4. Data analysis

The number of times the dog chose each reward was coded live during the test. Agreement between the E and the handler was perfect as the choice was unequivocal. As data were not normally distributed (Kolmogorov Smirnov, $ps < 0.05$), Wilcoxon Signed-Rank test was used to compare the number of trials in which the dogs chose liver with the number of trials in which dogs chose sausage.

4.5. Results and discussion

Dogs chose liver (mean: 6.88, SD: ± 1.36) significantly more often than sausage (mean: 3.11, SD: ± 1.36) ($Z = -2.53$, $p = 0.011$). On a descriptive level, one dog preferred liver 9 times out of the 10 trials, another picked it 8 times, five chose it 7 times and 1 selected it 6 times. These results suggest that liver may be a preferred reward for dogs and thus have a higher incentive value than sausage. However, although overall dogs seemed to prefer liver over sausage, individual differences in dogs' food preferences should be taken into account (e.g., Bremhorst et al., 2018).

This difference could explain the results of Study 1A. Specifically, if liver has a higher incentive value than sausage, then its discrepancy with dry food would be greater than the discrepancy between sausage and dry food. According to this, SNC was found in the group receiving liver but not in the one receiving sausage as a high value reward.

5. General discussion

Results show that dogs from the experimental group which received liver as the high quality reward, picked up less bones than the control group once they started receiving the low quality reward (dry food). This confirms the occurrence of a SNC effect in domestic dogs, which is in line with other studies in mammals. This result expands the findings of Bentosela et al. (2009) to a non-social task, and further supports the hypothesis that SNC is an effect that can be observed through a field experiment, as dogs were tested in their home environment and not in laboratory conditions.

However, remarkably, the SNC effect was not observed in the group receiving sausage as a high quality reward. It is possible that this inconsistency is due to the high quality rewards (liver and sausage) differing in their hedonic value. The discrepancy between the high and low quality rewards appears to be one of the most important aspects for the SNC effect to take place (e.g., Amsel, 1992). Similarly, Ruetti et al. (2009) found differences in the SNC effect in rats that experienced a large downshift (32% to 4% sucrose), but not when it was small (8% to 4% sucrose). Therefore, it is likely that the difference between liver and dry food is greater than the difference between sausage and dry food, which could justify the behavioral differences in both experimental groups. This idea is supported by the results from Study 1B, in which dogs preferred to eat liver more often than sausage, when they could pick between both of them. Furthermore, this could also explain the lack of SNC effects found in Pongrácz et al. (2013); Riemer et al. (2016) and Riemer et al. (2018), as these works used sausage as the high quality reward.

In addition, it must be remarked that there were no significant group effects neither during the preshift nor the reshift phase. Thus, dogs from EL and ES groups behaved similarly to the controls when receiving the high quality reward, which usually meant picking up all the available bones as this task was relatively easy. Moreover, the preshift phase showed a significant effect of trial, which implies a learning effect as the task carries on. In line with this, most dogs completed the task faster as they were repeatedly exposed to it.

Regarding the time spent in proximity to the toy, surprisingly there was only a tendency for the EL group to spend less time close to it than ES and C groups. This was unexpected as surprising reward changes usually elicit withdrawal responses from the feeding source. This behavior has been previously observed both in dogs (Bentosela et al., 2009, but see Riemer et al., 2018) and other mammals (e.g., rats in Papini and White, 1994), suggesting an aversive emotional state due to the downshift in the reward. It is possible that dogs on this study may not have experienced such an aversive negative state that led them to avoid the feeding source. Riemer et al., 2018 proposed that dogs may not be as sensitive to reward loss as other mammalian species due to their artificial selection and lifetime experiences. These authors suggest that, together with their selection for higher trainability, dogs may have been selected for reduced sensitivity to reward loss. Moreover, pet dogs are exposed to an enriched environment during their daily lives, which could reduce their sensitivity to the devaluation of a reward, as it has been observed in rats (Burman et al., 2008). Finally, intermittent reinforcement during their lives may have made them more resistant to variations in reward quality or omission (Amsel, 1992).

One point to be considered, is that the test was carried out in the absence of the owner, which may have been stressful to the dogs' and could have affected their motivation during the task (e.g. Topál et al., 1998, but see Müller et al., 2012). This may have exacerbated the appearance of SNC effects in this situation. Future research on this topic could be carried out with the owner present in the room but not participating in the task.

Moreover, future studies of SNC in dogs would also benefit from a more detailed measurement of the animals' emotional state. Behaviorally this could include the display of stress signals, such as low ears and tail, whining or lip licking (e.g., Gazzano et al., 2014). Additionally, concomitant measures of glucocorticoids, like cortisol, could provide information related to the physiological aspects of SNC. This would be expected, as it has been observed that rats experience an increase in corticosterone on the second day postshift (Flaherty et al., 1985). These findings would be useful to add information regarding dogs' reaction to potentially stressful situations, and thus be used in the assessment of animal welfare (Beerda et al., 1997).

It has been argued that the social aspect of interaction with the experimenter was a confounding variable in previous studies of SNC in dogs (Pongrácz et al., 2013; Riemer et al., 2016). In particular, Pongrácz et al. (2013) suggested that dogs may not be as sensitive to reward quality when communicating with humans, given the strong bond between both species. Similarly, Riemer et al. (2016) proposed that future studies should assess SNC effects in dogs using tasks that do not rely on the direct interaction of the dog and the experimenter. Therefore, one of the aims of the present study was to evaluate SNC in dogs during a non-social task, which was observed in the current work. However, Bentosela et al. (2009) found SNC in dogs during a social task, so debate still remains open regarding the effects of experimenter interaction on this phenomenon. Further research of SNC in social tasks is needed to further disentangle this point of debate.

In conclusion, the present study found evidence of SNC in dogs during a non-social task. Additionally, this was observed in the dogs' environment, outside of a laboratory context. This gives greater external validity to the obtained results, as well as highlights that SNC is not only a laboratory phenomenon associated with better experimental control.

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