



Functional cerebral asymmetry in dogs living under different environmental conditions



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ABSTRACT

Investigating the link between stress and functional cerebral asymmetry (FCA) has been a subject of interest in recent years. The demonstration of this link in the field of veterinary medicine is particularly important as measuring FCA has the potential to be an alternative and non-invasive behavioral method to assess stress in dogs. The present study aimed to investigate whether FCA is affected by different environmental conditions in dogs.

The main aim of this study was to investigate the changes in FCA in dogs living under different conditions. To this aim, strength and direction of FCA in 40 urban free-ranging dogs were measured by a Kong test. Dogs were divided into four groups considering their environmental conditions: The dogs in Group 1 (n = 8) were rehabilitated urban free ranging dogs, which were kept in enriched shelter conditions. The dogs in Group 2 (n = 9) were adopted free ranging dogs, which lived in home environment for more than 1 year. The dogs in Group 3 (n = 11) were urban free ranging dogs, which stayed in individual cages in a dog shelter for more than 6 months. The dogs in Group 4 (n = 12) were adopted urban free ranging dogs, which stayed in a dog pension for more than 30 days. Considering the length of their stay in a kennel environment, quality of living condition and emotional states, the dogs in Group 3 and 4 were classified as chronically stressed dogs.

Statistically significant differences existed between groups considering strength and direction of lateralization. Most of the dogs in Group 1 (87.5 %) and Group 2 (77.8 %) showed significant paw preferences, whereas most of the dogs in the Group 3 (72.7 %) and Group 4 (75 %) were categorized as ambilateral. Considering the individual level asymmetry in dogs and environmental conditions of dogs in Group 3 and 4, one may suggest that high ambilaterality levels is related with chronic stress. Thus, reduced FCA may not be the reason for stress sensibility, rather it can be an outcome of stressful situations. These results are the first to demonstrate the possible link between chronic stress and ambilaterality in dogs.

1. Introduction

Cerebral lateralization refers to the functional and anatomic specialization of brain hemispheres. Functional cerebral asymmetry (FCA) is defined as a specialization of brain hemispheres in order to control certain motor functions of the organism (Ocklenburg et al., 2014). Cerebral lateralization has been manifested in many species such as dogs (Branson and Rogers, 2006; Batt et al., 2007; Siniscalchi and Quaranta, 2014), cats (Siniscalchi et al., 2016), horses (Basile et al.,

2009), sheep (Versace et al., 2007) and even avian species such as chickens (Rogers, 2008), sparrows (Franklin and Lima, 2001) and also in cetaceans (Siniscalchi et al., 2012)

Several studies show the relationship between stress and laterality (Wittling et al., 1998; Richardson, 1993; Hausmann and Güntürkün, 2000). It is proposed that dominant hemisphere to process information during stress is right hemisphere, as right hemisphere is specialized to control strong emotions and emergency responses such as escape and aggression (Rogers et al., 1985; Vallortigara et al., 1998; Lippolis et al.,

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2005) and further to control physiological stress responses such as increased heart rate (Wittling et al., 1998) and pituitary-adrenal axis (Wittling and Pfluger, 1990). Left hemisphere, on the other hand, is responsible for processing positive emotions (Davidson et al., 1995) and “sequential processing”, i.e. the mechanism which enables the individual to focus on and assess the situation (Bianki, 1983). Many authors suggested that right brain dominance is associated with more sensitiveness to stress and, thus, right hemisphere dominant individuals display more defensive and withdrawal behavior (Carlson and Glick, 1989; Henry, 1997; Sullivan and Gratton, 2002). For instance, a recent study assessing the asymmetric tail wagging in dogs showed that approach tendencies in dogs are associated with the left hemispheric activation, whereas withdrawal tendencies associated with the right hemispheric activation (Siniscalchi et al., 2013). Moreover, dogs had right hemispheric activation while processing negative emotional vocalization of the owners (Siniscalchi et al., 2018).

According to Rogers (2010), not only direction but also the strength of lateralization are important indicators of well-being since the direction of the lateralization would indicate the ongoing state of optimism and pessimism while weaker or lack of lateralization may cause an individual to show higher reactivity to stress. Reddon and Hurd (2009) also suggested that since the action is the consensus of the two hemispheres, this consensus-making process is likely to take additional time in the weakly lateralized brain. Thus, animals with a weakly lateralized brain are likely to be more anxious. These animals may also be less capable of coping with different stimuli simultaneously.

It is further suggested that functional cerebral asymmetry changes over short or long periods (Rentería, 2012). Considering the fact that the right hemisphere is more active during acute stress, it is proposed that FCA in individuals with left hemisphere dominance decreases in case of acute stress, while it further increases in individuals with right hemisphere dominance (Ocklenburg et al., 2016). Moreover, it was reported that traumatic events may cause a shift to right hemisphere dominance as a result of long-term changes in neural activity and neurotransmitter levels of neural pathways in the right hemisphere (Adamec et al., 2005). Another mechanism proposed in this issue emphasizes the effects of glucocorticoids on neuronal mechanisms. Increased cortisol levels in response to acute stress increases glutamatergic conduction in different areas of the brain (Popoli et al., 2012), whereas it reduces GABAergic neuronal conduction (Mody and Maguire, 2012). Concerning this mechanism, Ocklenburg et al. (2016) suggested that acute stress-related cortisol release increases FCA, while chronic stress reduces FCA in a different way. Accordingly, chronic stress reduces FCA by causing the volume of the corpus callosum to decrease.

In dogs, FCA was assessed by observing different functions such as asymmetric tail wagging (Quaranta et al., 2007), head orientation to acoustic stimuli (Siniscalchi et al., 2008) and paw preferences (Wells, 2003; Branson and Rogers, 2006; Batt et al., 2007). Limb preferences during simple tasks reflect an individual's preference to use a certain hemisphere (Rogers et al., 2013). A recent meta-analysis has shown that 68% of the dog population showed individual level asymmetry (Ocklenburg et al., 2019). Namely, they either show right or left bias in their paw preferences (Poyser et al., 2006; Barnard et al., 2018). According to Branson and Rogers (2006), dogs with the weaker strength of paw preference are more sensitive to stress in comparison to their conspecifics with strong paw preference. They, moreover, hypothesized that non-lateralization which may be caused by the lack of inhibition of left hemisphere over right hemisphere associated with intense emotional responses to stress. Batt et al. (2007) also reported that the strength of paw preference is associated with confident and relaxed behavior in dogs.

It is well known that admittance to the kennel and/or shelter environment emerges physiological and behavioral stress responses in dogs due to psychogenic stressors such as novel environment, noise, restraint and separation from social attachment figures (Hennessy et al.,

1998; Stephen and Ledger, 2006). A longer period of kenneling is also associated with an impaired welfare and therefore, responses displayed during chronic stress are regarded as valid indicators of canine welfare (Bearda et al., 1997). Recent studies showed the importance of social contact, training and rehabilitation programs in order to reduce stress and increase welfare in shelters (Wells, 2004; Luescher and Medlock, 2009; Salgirli Demirbas et al., 2017). Thus, the welfare of dogs in shelters/kennels for longer periods is mostly dependent on environmental optimization including predictable routines and opportunities for social contact (Salgirli Demirbas et al., 2017).

This study was designed to assess the changes in FCA of dogs living in different environmental conditions. Thus, it was aimed to assess whether FCA is affected by environmental conditions causing chronic stress in dogs. To this aim, the strength as well as the direction of FCA of four groups of urban free-ranging dogs were assessed. It was hypothesized that chronic stress and ambilaterality may be related in dogs and, thus, that measuring FCA with an easy test such as the Kong® test would be a promising tool to assess chronic stress in dogs.

2. Material and Methods

2.1. Subjects

Forty urban free-ranging dogs (range: 2 to 8 years old) were categorized into four groups according to their environmental conditions such as meeting their physiological needs, quality of the housing, expression of natural behavior and emotional states.

The dogs in Group 1 were rehabilitated urban free ranging dogs which were kept in an enriched shelter environment. All rehabilitated dogs in Group 1 (n = 8) successfully completed a rehabilitation program including steps such as “protocol for deference” (Overall, 2013), basic obedience and adaptability to the home environment which lasted one month. The emotional states of those dogs were stated as positive after an emotional assessment (Salgirli Demirbas et al., 2017).

The dogs in Group 2 (n = 9) were adopted free ranging dogs. They should meet three criteria to be involved in this study: i) prior street life experience, ii) minimum 1 year of time spent in home environment after the adoption, iii) should have minimum 1-h outdoor daily exercise. Their emotional states were evaluated as positive after a behavioural assessment was applied by a specialized behaviorist in home environment. None of the dogs have displayed any behavioural disorders.

The dogs in Group 3 (n = 11) were urban free ranging dogs which stayed in a shelter for more than 6 months. After a short test situation and welfare assessments, emotional states of the dogs were stated as negative and the quality of housing condition was stated as very poor. According to the observer report, the floor material was not convenient for dogs, no visual barrier was provided for the dogs to ensure privacy and security and also none of the cages had isolation or shade to protect the dogs from hot/cold weathers. The dogs had no comfortable resting places in their own cages. They were kept in individual cages without any direct positive social interaction neither with other dogs nor with humans. They neither received training nor got involved in a rehabilitation program. They further had no access to free activity such as play, walk or exploration.

Dogs in Group 4 (n = 12) were urban free ranging dogs, which had been adopted from streets. They stayed in a dog pension mainly because owners were abroad. Minimum length of stay in kennels was 38 days for this group. Considering restriction in size and complexity of the environment, limited environmental and social stimulation as well as absence of the owner in a kennel environment, the environmental condition was classified as restrictive, unnatural and unpreferred which are indicators of poor welfare in dogs (Fraser and Duncan, 1998). Furthermore, the evaluators were assessed the emotional states of the dogs as negative after the emotional assessment. As 4-6 weeks of social and special restriction can be used as a chronic stress model for dogs

(Beerda et al., 1999a, Beerda et al., 1999b), considering the length of their stay, quality of living condition and emotional states, the dogs in Group 3 and 4 were classified as chronically stressed dogs in our study.

2.2. Kong test

The Kong® test was used in this study to assess strength as well as lateralization in dogs. The Kong® test was conducted based on the study by Batt et al. (2007). All dogs were tested in an enclosure such as a room or a kennel. The Classic Kong® Toy was filled with a mixture of palatable food (meat and dry cat food) and placed into a frozen for a minimum of 12 hours. The Kong toy was presented to the dog on a flat surface. Total of 50 left paw (L) plus right paw (R) scores were counted by a direct observation, irrespective of the number of bimanual (B) scores.

2.3. Statistical Analysis

For all statistical tests, SPSS software was used. A laterality index (LI) of motor preference can then be calculated as $(R - L) / (R + L)$. According to this equation, R refers to the number of times the right paw is used, whereas L indicates the number of times the L paw is used. The strength of lateralization was measured using the laterality index regardless of its direction, i.e., the absolute value of LI. The significance of paw preference was determined using binomial z-score for each dog [$z = (R - 0.5N) / \sqrt{(0.25N)}$]. Accordingly, the dogs with a positive z score value ($z \geq 1.96$) were scored as R-pawed, whereas those with a negative z score value ($z \leq -1.96$) were scored as L-pawed. The other dogs were determined as ambilateral (A). Chi-square test was used to compare group results for paw preference. Kruskal-Wallis was used to compare the strength of lateralization among groups. The results were considered significant if $p < 0.05$.

3. Results

3.1. Direction and strength of lateralization

The individual paw preferences of the dogs are presented in Table 1. According to z-scores, most of the dogs in Group 1 (87.5 %) and Group 2 (77.8 %) were showing strong paw preferences, whereas most of the dogs in Group 3 (72.7%) and Group 4 (75 %) were assessed as ambilateral (Fig. 1). Accordingly, the number of lateralized dogs is significantly higher in Group 1 and 2 in comparison to that in Group 3 and Group 4 ($X^2 = 12,551$, $p = 0.006$). There were also significant differences among groups considering the strength of lateralization (Kruskal-Wallis, $p = 0.019$, Table 1). Lateralization was significantly stronger in Group 1 and Group 2 in comparison to Group 4 (Mann-Whitney U, $p = 0.010$ [Group 1 to 4], $p = 0.028$ [Group 2 to 4])

3.2. Comparison of lateralization according to sex

No significant association was found between laterality and sex ($X^2 = 1.667$, $p = 0.197$). Table 2 shows paw preferences of the dogs according to sex.

Table 1
Absolute LI values according to the groups.

Parameter	Group	N	Mean	Median	Minimum	Maximum	p
Absolute LI	1	8	0,46 ^a	0,45	0,08	0,80	0,019
	2	9	0,37 ^{ab}	0,36	0,08	0,68	
	3	11	0,21 ^{bc}	0,12	0,00	0,60	
	4	12	0,19 ^c	0,16	0,00	0,56	

*a, b, c: The different letters in the same column represent a statistically significant difference ($p < 0.05$).

4. Discussion

The findings of the present study showed that ambilaterality was significantly more common in dogs exposed to a stressful environment. Accordingly, it can be suggested that chronic stress decreases FCA, i.e. strength of paw preference and, further, causes ambilaterality in dogs. It is well known that most of the dogs have a greater preference to use their either left or right paw. Thus, they have an individual level asymmetry and ambilaterality is not common in dogs under normal circumstances (Barnard et al., 2018; Ocklenburg et al., 2019).

Although effect of stress on FCA could not yet been fully understood, effects of acute stress on FCA is mostly explained by the right shift theory in dogs (Siniscalchi et al., 2008). Considering the link between left paw preference and higher susceptibility to stress in dogs (Batt et al., 2009; Barnard et al., 2018), one may expect that FCA increases in those individuals in case of stress as a result of right hand dominance. Only the individuals with right paw preferences are expected to have weak FCA under these circumstances. However, considering the number of dogs showing ambilaterality under a chronic stress situation in this study, this explanation does not seem to fit for chronic stress situation. In a study conducted by Branson and Rogers (2006), it was shown that the dogs without a significant paw preference were more reactive to the sounds than the dogs with paw preference. This brings an important question as to whether weakly lateralized dogs are more prone to stress or dogs are weakly lateralized due to chronic stress resulting from anxiety and fear.

Although the link between chronic stress and FCA has not yet been studied in dogs, in humans ambilaterality was shown to be related to several psychiatric conditions such as phobias and post-traumatic stress disorder (PTSD) (Chemtob et al., 2002; Saltzman et al., 2006). Effects of chronic stress on FCA is explained by the structural changes in the brain (Ocklenburg et al., 2016). It was also demonstrated that structural changes in the brain, i.e. reduced volume of corpus callosum decreases FCA in humans in a chronic stress situation (Saar-Ashkenazy et al., 2014). A recent meta-analysis has demonstrated that dogs mainly have side bias paw preferences in under normal circumstances (Ocklenburg et al., 2019). Accordingly, it can be expected that the dogs exposed to a chronic stress situation show decreased FCA similar to humans. Thus, ambilaterality may not be the reason but the outcome of the stressful situation. In one study, it was further shown that individuals having more severe PTSD symptoms show a higher degree of mixed laterality (Saltzman et al., 2006). Thus, one may assume that the level of stress is also an important factor in the modulation of FCA.

Another interesting result of this study is the similar paw preferences shown by rehabilitated urban free ranging dogs in shelters and urban free ranging dogs living in a home environment. According to Rogers (2011), an aim of welfare would be enabling to a balanced use of both hemispheres. It was further reported that weak lateralization and/or non-lateralization means a reduced ability of left hemisphere to inhibit the right one (Rogers, 2010). Therefore, encouraging the activity of left hemisphere by training on simple tasks was recommended to help improving the welfare of an animal already suffering stress or increased fear (Rogers, 2011). This hypothesis is supported by the current study findings indicating that dogs in a rehabilitation program showed stronger lateralization than sheltered dogs without any history of training or rehabilitation. Furthermore, one may assume that the welfare condition and emotional states of rehabilitated urban free-ranging dogs in the shelter are better than those of urban free-ranging dogs in shelters without any training or rehabilitation. Accordingly, it may be suggested that conducting simple programs including daily positive interactions with dogs, playing periods and training on simple tasks have a significant impact on the welfare of shelter dogs.

Finally, some limitations of this study should also be acknowledged. First, the sample size for each group was relatively small. Second, due to the low adoption rates in our shelters before and after evaluations were not applicable for all of the dogs. Further studies including

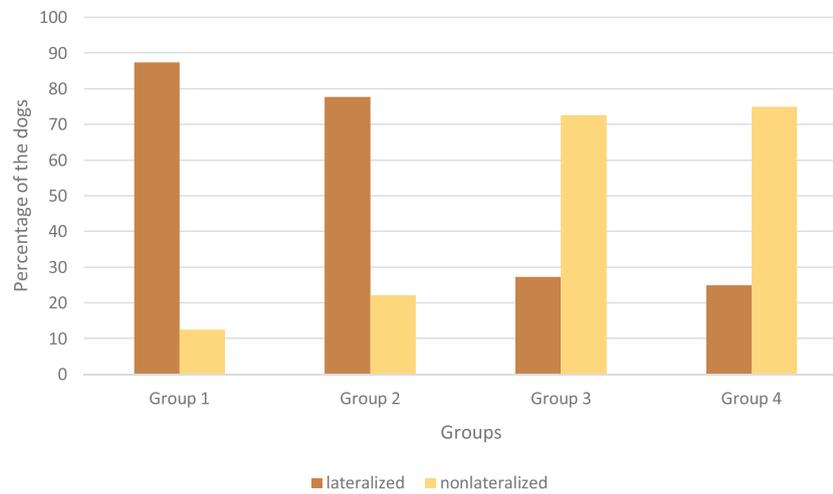


Fig. 1. Distribution of paw preferences.

Table 2

|LI| values of the dogs according to sex.

Dogs	Group	Sex	LI
1	1	Male	0,08
2	1	Female	0,36
3	1	Female	0,36
4	1	Female	0,6
5	1	Female	0,54
6	1	Male	0,28
7	1	Male	0,64
8	1	Male	0,8
1	2	Female	0,28
2	2	Male	0,68
3	2	Female	0,08
4	2	Female	0,36
5	2	Female	0,52
6	2	Male	0,32
7	2	Female	0,2
8	2	Female	0,4
9	2	Male	0,52
1	3	Female	0,6
2	3	Male	0
3	3	Male	0,08
4	3	Female	0,38
5	3	Female	0,04
6	3	Female	0,48
7	3	Male	0,12
8	3	Male	0,12
9	3	Male	0,12
10	3	Male	0,2
11	3	Female	0,12
1	4	Female	0,24
2	4	Male	0,16
3	4	Female	0,4
4	4	Female	0,24
5	4	Female	0,04
6	4	Male	0,08
7	4	Female	0,56
8	4	Female	0,16
9	4	Female	0,04
10	4	Male	0
11	4	Female	0,08
12	4	female	0,28

increased group sizes and before-after evaluations would allow for verifying the findings of this study.

5. Conclusions

Recently the link between emotional stress and cognitive processes is the focus of interest. This study is the first research demonstrated that

chronic stress and reduced FCA may be related in dogs. Moreover, considering the plasticity of the brain organization, reduced FCA may not be the reason but the result of emotional reactivity in dogs. Despite the limitations of this study, the results of this study may help to better understand the link between asymmetric hemispheric organization and stress in dogs. However, further studies are needed to investigate the interplay between chronic stress and FCA in dogs.

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