Predicting Dogs' Training Ease and Behavior using their Neural Responses to Discriminative Odors

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Introduction: Humans have long made use of olfactory detection capabilities of dogs. Those capabilities have been harnessed for tracking other people [1] and searching for a variety of materials by scent, including hazardous materials such as explosives [2]. Dog training can be expensive due to the manpower and time involved. Therefore, predicting the training ease as well as behavioral capabilities (such as hunting, retrieving and environmental soundness) of working dogs before their recruitment will be of enormous benefit. In order to identify endophenotypes of superior working dogs (which may identify more trainable dogs prior to training), we explored the possibility of characterizing the canine olfactory system using functional MRI, one of the most popular non-invasive approaches for measuring brain activity. Since anesthetized dogs cannot sniff, we imaged conscious dogs using our recently published experimental procedure [3]. We investigated the correlation of canine behavior with imaging metrics derived from activation to discriminative odors, in order to predict dogs' training ease and behavior based on their brain activation.

Methods: A single-shot gradient-recalled echo-planar imaging (EPI) sequence [4] was using to acquire the T2*-weighted functional images. The parameters of data acquisition are as following: TR=1000 ms, TE=29 ms, FA=90 °, FOV=192 ×192 mm^2, in-plane resolution 3×3 mm^2, in-plane matrix 64×64, slice thickness 3 mm and 14 axial slices to cover the whole brain. Six dogs were trained, using positive reinforcement behavior shaping procedures [5], for keeping their head still while they were presented with olfactory stimulus using a computer controlled device as in [3]. Three dogs were trained to alert (outside the scanner) to the presence of odorant A (Eugenol) and another set of three were trained to alert to the presence of odorant B (Ethyl Butyrate). Thus, for half the dogs, odorant A was the discriminative stimulus and odorant B was the non-discriminative stimulus and this was reversed for the other half of the dogs. The dogs were trained to remain still inside the scanner even for the discriminative odor, with the assumption that they would identify it as the discriminative odor based on extensive prior exposure outside the scanner to that odorant as the discriminative one. At least three discriminative odor runs and three non-discriminative odor runs of useable data were acquired for each dog. The functional MRI data obtained from each of the dogs was corrected for motion using rigid-body realignment, corrected for slice timing, normalized to the anatomical of one of the dogs, spatially smoothed, detrended and input into a general linear model (GLM) using SPM 8 [6]. F test was performed to obtain activation maps (both single subject and group-level) by comparing the two odor conditions (discriminative odors vs. non-discriminative odors). Time and dispersion derivatives were considered in the design matrix in order to account for variability of the hemodynamic response.

Results and Discussion: Canine behavior was characterized using two metrics: an integrated behavioral score capturing their hunting, retrieving, and environmental soundness and a training ease score based on the ease with which dogs could be trained. We found that the discriminative odorant stimulus lead to higher activity compared with non-discriminative stimulus in olfaction-related and higher order brain areas of the canine brain such as olfactory bulb, frontal cortex, piriform lobe, cerebellum, hippocampus and caudate (see Fig.1), which is similar to the results obtained in human studies [7,8]. Importantly, activation magnitude in these regions were significantly correlated with integrated behavior and training ease (see Fig.2&3). If this effect can be replicated and shown to be robust in future studies, fMRI-based neural response to discriminative odors may serve as an endophenotype for desirable canine traits/behavior and superior training ease.

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References: **1.** Sommerville, et al, Animal Behavior 14:189 - 190, 1993. **2.** Furtona., *et al*, Talanta 54 (3): 487–500, 2001. **3**. Jia., *et al,* PLoS ONE 9(1): e86362, 2014 **4.** Butts, *et al*, Magn Reson Med 31: 67–72, 1994 **5.** Hiby, *et al*, Animal Welfare 13: 63-69, 2004 **6.** Statistical Parametric Mapping, http://www.fil.ion.ucl.ac.uk/spm/ **7.** B. Cerf-Ducastel, et al, NeuroImage 31(1): 386-396, 2006. **8.** Plailly, et al, NeuroImage 24(4): 1032-1041, 2005

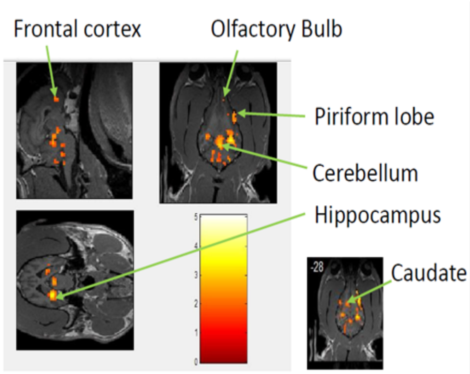

Fig.1 Regions of the awake dog brain which were significantly more activated for discriminative odors vs non-discriminative odors

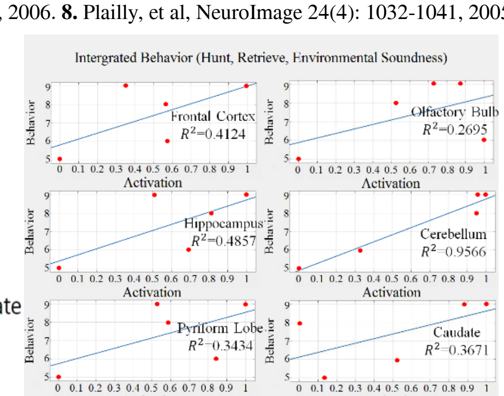

Fig.2 Correlation between activation magnitude in the odor task and integrated behavioral score for all brain regions which were more activated for discriminative vs non-discriminative odors

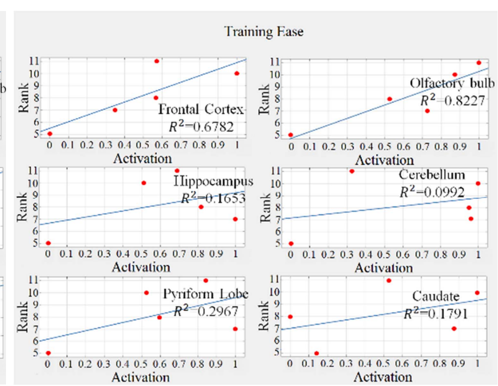

Fig.3 Correlation between activation magnitude in the odor task and training ease behavioral score for all brain regions which were more activated for discriminative vs non-discriminative odors