Laboratoire d'Éthologie Expérimentale et Comparée (LEEC)

Research Proposal for a PhD thesis – 2023

Behavioural and neural mechanisms underlying cognitive styles in a social insect

Thesis supervisor

Patrizia d'Ettorre, Professor, d-ettorre@univ-paris13.fr
Laboratoire d'Ethologie Expérimentale et Comparée (LEEC),
Université Sorbonne Paris Nord

Application Procedure – deadline 25/05/2023

Applicants should send CV and motivation letter
(in one single PDF file) to d-ettorre@univ-paris13.fr

Context. Not everyone behaves the same when solving a problem. Within-individual variations in task performances is common both in humans and in non-human animals[1]. Different cognitive styles (stable relationships between different cognitive abilities) are the consequence of the specific strategy by which each individual perceives, processes, stores and uses information to solve cognitive tasks. This strategy should be consistent across time: individuals show repeatable learning and decision-making styles[2].

Since the early 1900s[3], the scientific community has been questioning the existence of general cognitive abilities allowing the solution of multiple problems, or of a modular system based on cognitive subunits that evolved to solve specific problems (general vs modular intelligence)[4,5]. The study of cognitive styles may help solve this debate. The PhD project aims at investigating inter-individual variation in cognitive strategies to understand the organization of cognitive processes and the general or modular nature of cognition.

As study organisms, we choose the ants, which show one of the most advanced social organization among social insects. Ants are appropriate model organisms for this project because they display a rich ensemble of cognitive skills, from associative learning to flexible tool use and quantitative cognition[6-10]. Ants are easy to handle and to rear in the laboratory, and their brain is relatively simple and experimentally more accessible than that of vertebrates. We will use ant species with monomorphic workers (morphologically similar, *Formica fusca, Lasius niger*) and with polymorphic workers (e.g. minor and major workers, *Messor barbarus, Camponotus aethiops*).

Objectives – A). Characterization of cognitive styles and their repeatability. We will focus on learning abilities, such as associative learning, reversal learning and spatial learning. Based on our previous work[6-10], we expect repeatable inter-individual variation in learning performance. We expect this inter-individual variation in cognitive performance to be stronger in monomorphic than in polymorphic species, since workers in polymorphic species are characterized by fixed developmental trajectories. Each ant will be tested repeatedly in at least 3 different tasks. The correlation in performance among these different tasks will inform about the general or modular nature of the cognitive style. Behavioural analysis will be performed from video-recordings using deep learning, e.g., the fine-tuned animal tracking software DeepLabCut[11]. B). Neural correlates of cognitive performance (collaboration with Dr. Jean-Christophe Sandoz, CNRS, Gif-sur-Yvette). Different cognitive styles may be characterized by differences in neuroanatomical (structure of brain centers) and neurophysiological (functioning of brain centers) hallmarks. We expect that ants with high performance in different cognitive tasks will show augmented volume/connectivity in various brain structures and higher stimulus-evoked activity, compared to ants that perform poorly in the same tasks. Dr. Sandoz has long lasting experience in neuroethology of social insects[12-14]. The PhD student will have the great opportunity to familiarize with these techniques.

References: **1**. Herrmann E, Call J (2012) Are there geniuses among the apes? Phil Trans R Soc Lond B 367, 2753–61. **2**. Cauchoix M et al. (2018) The repeatability of cognitive performance: a meta-analysis. Phil Trans R Soc Lond B 373, 20170281. **3**. Spearman C (1904) "General intelligence", objectively determined and measured. Am J Psychol 15, 201-293. **4**. Shettleworth SJ (2012) Modularity, comparative cognition and human uniqueness. Phil Trans R Soc Lond B 367, 2794–2802. **5**. Burkart JM, Schubiger MN, van Schaik CP (2017) The evolution of general intelligence. Behav Brain Sci 40, e195. **6**. Guerrieri FJ, d'Ettorre P (2010) Associative learning in ants: conditioning of the *maxilla-labium* extension response in *Camponotus aethiops*. J Insect Physiol 56, 88-92. **7**. Perez M, Rolland U, Giurfa M, d'Ettorre P (2013) Sucrose responsiveness, learning success, and task specialization in ants. Learn Mem 20, 417-420. **8**. Piqueret B, Bourachot B, Leroy C, Devienne P, Mechta-Grigoriou F, d'Ettorre P*, Sandoz JC* (2022) Ants detect cancer cells through volatile organic compounds. iScience 25, 103959. **9**. Maák I, Roelandt G, d'Ettorre P (2020). A small number of workers with specific personality traits perform tool use in ants. eLife 9, e61298. **10**. d'Ettorre P, Meunier P, Simonelli P, Call J (2021) Quantitative cognition in carpenter ants. Behav Ecol Sociobiol 75, 86. **11**. Mathis A., Mamidanna P, Cury KM, Abe T, Murthy VN, Mathis MW, Bethge M (2018) DeepLabCut: markerless pose estimation of user-defined body parts with deep learning. Nature Neuroscience 21, 1281-1289. **12**. Sandoz JC (2006) Odour-evoked responses to queen pheromone components and to plant odours using optical imaging in the antennal lobe of the honey bee drone *Apis mellifera*; J Exp Biol 209, 3587-3598. **13**. Hourcade B, Perisse E, Devaud JM, Sandoz JC (2009) Long-term memory shapes the primary olfactory center of an insect brain. Learn Mem 16, 607-615. **14**. Dupuy F, Josens R, Giurfa M, Sandoz JC (2010) Calcium imaging in the ant *Camponotus fellah* reveals a conserved odour-similarity space in insects and mammals. BMC Neuroscience 11, 28