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Looking at lateralization as a dynamic and plastic feature of nervous systems

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Commentary on “Laterality 2020: entering the next decade” by Sebastian Ocklenburg, Gesa Berretz, Julian Packheiser & Patrick Friedrich

Looking at lateralization as a dynamic and plastic feature of nervous systems

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Abstract

In the last few decades, research on lateralization has expanded our knowledge about the manifestation, development, and mechanisms of this fascinating feature of nervous systems. This has been possible not only thanks to human studies, but to the use of animal models and the introduction of ground-breaking techniques within this research field. However, recent studies have also demonstrated how complex this phenomenon is and highlighted that we still lack a complete understanding of brain and behavioural asymmetries. Here, I comment on two of the challenges presented by Ocklenburg and colleagues that research on lateralization has to face in the next future. I argue that, in order to improve our understanding of lateralization, we have to consider it as a dynamic and plastic characteristic, which is strongly influenced by both internal factors, such as an animal’s motivation and emotional states, and external factors, including the physical environment and the social context.

The paper by Ocklenburg and colleagues (2020) gives us a good overview of the future directions that research on lateralization should take in the next decade, considering the gaps that need to be filled and the new cutting-edge approaches that will allow scientists to do so.

I agree with the general points raised by the authors and I share with them the idea that we should work together to take the research on lateralization a step further. In particular, I would like to stress the importance of two of the main goals our colleagues are encouraging us to reach in the next future: i) **the reaching of unbiased conclusions about true effects** (in relation to the first 3 points of Ocklenburg and colleagues’ paper); and ii) **the need of empirical studies testing several species through ecologically meaningful procedures** (with respect to points 6 and 7).

As regards the first aspect, I believe we need to be extremely careful in designing our experiments as small changes in the experimental protocol may affect behavioural biases. In experiments with non-human species, for example, behavioural lateral biases are often assessed using a T-maze or Y-maze apparatus (e.g., in invertebrates; Frasnelli, 2017). However, very few studies have considered the motivation of an animal when entering a maze and how this might influence the arm chosen.

For instance, in cuttlefish, the use of shelters at the end of the maze’s arms induces a leftward bias, but no bias is displayed when the shelters are removed (Jozet-Alves et al., 2012). We observed something similar in bumblebees (Waite & Frasnelli, 2020). When tested for the mere exploration of the T-maze apparatus, bees did not display any turning bias. However, when

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trained to associate a visual stimulus with a sucrose reward and then presented with the same visual stimulus at the end of both arms, the bees showed a population-level bias in turning towards the right arm (Waite & Frasnelli, 2020). Red bugs (*Dysdercus andreae*) present a leftward turning bias when released in a T-maze, but when the bugs are blown with air before being placed in a T-maze, the bias is no longer displayed (Rivero-Aragon et al., 2018). This suggests that the manifestation of lateralization can be affected by stress. These are just three examples of how behavioural biases in lateralization are displayed or not depending on small differences in the experimental protocol, and should serve as an input to conduct more research to understand the effect of motivation and emotional state, such as stress, on lateralization within the same task.

Moreover, I believe this research field would benefit from the use of new techniques that allow recording the behaviour and assessing behavioural lateralization in fine details as it is impossible to do by human eye. This would not only avoid any possible behavioural bias induced by the observer, but it would also consent to consider parameters otherwise impossible to measure. In this regard, tracking systems of free-moving animals may prove to be an extremely valuable tool. The close-loop virtual reality technique, for example, allows to track the position of the animal while moving in an arena in real time, and present it with visual stimuli on a 2D screen that move with the animal to create the virtual illusion of being in a 3D world. This technology has been recently employed in the study of how free-flying bees avoid virtual obstacles (Frasnelli et al., 2018) and could be successfully used to investigate visuomotor biases. Highly specialised approaches like this might, however, be confined to very studies, making it difficult to replicate results across different species. In fact, as discussed by Ocklenburg et al. (2020), reproducibility of results remains a challenge.

In relation to the second aspect that I would like to discuss, the authors wrote: *"Ideally, the manifestation of cognitive abilities should be tested across taxa, across contexts and with multiple converging tasks to gain a more robust understanding of a species cognitive profile and the evolutionary trajectory of cognitive phenomena."* (Oklenburg et al., 2020). I could not agree more with this statement. Indeed, we do not only need, as I wrote above, to test animals in different motivational and emotional contexts, but also in different tasks and across different related (and not related) species to gain insights into the evolution of this fascinating feature of nervous systems.

Closely related species of bees, for example, are valuable models to investigate the evolution of lateralization (Frasnelli et al., 2014). In particular, they have allowed us to test important predictions about the role of social pressures to align behavioural asymmetries within a given population. Population-level lateralization (i.e., in single individuals and in the same direction in most of them so that the population is biased) has been suggested to evolve as an Evolutionarily Stable Strategy when lateralized individuals need to coordinate their behaviour with that of other lateralized individuals (Ghirlanda et al., 2009). Different species of bees showing different levels of social organisation have provided empirical evidence in support of this idea and suggested that behavioural asymmetries might vary depending on the actual social pressure in specific tasks (Niven & Frasnelli, 2018). Specifically, solitary mason bees do not present population-level lateralization in learning and recall olfactory memories as eusocial honeybees and primitively social Australian stingless bees do (reviewed in Frasnelli et al., 2014), but they show population-level lateralization in the way they interact aggressively with conspecifics (Rogers et al., 2016). In other words, the same individual can be more or less strongly biased in a specific direction depending on whether or not it is interacting with other individuals (for a discussion on this, see Frasnelli & Vallortigara, 2018).

This implies that lateralization is not necessarily a static feature of the neural organisation; rather, the way it is manifested in behaviour is modulated by the functional (social) context. The next decade of research on lateralization should then consider this and should think about lateralization as a dynamic and plastic feature of nervous systems that can be influenced by external stimuli.

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