Dear Sir/Madam,

We submit for your attention our manuscript, entitled: “Neural coding in the visual system of *Drosophila melanogaster*: How do small neural populations support visually guided behaviours?”, for inclusion in PLoS Computational Biology.

A general problem in neuroscience is understanding how sensory systems organise information to be at the service of behaviour. Computational approaches have always been important in this endeavour, as they allow one to simulate the sensory experience of a behaving animal whilst considering how this information is transformed by populations of neurons. Thus we can relate the details of neural circuitry to theories about the requirements of behaviour. In visual neuroscience, a rare opportunity has emerged to understand how visually guided behaviours are mediated by particular visual encodings. Specific small sub-populations of identifiable neurons in *Drosophila* are known to be necessary for particular visual tasks and the individual receptive fields of the neurons in these populations have now been described in detail. Surprisingly, these populations are small, with only twenty or so neurons, which suggests something of a sensory bottleneck. In our manuscript, we consider how the population code from these neurons relates to the information required to control specific behaviours in *Drosophila,* by analysing the neural outputs that result from simulations of classic *Drosophila* experiments. We conclude that, despite previous claims, *Drosophila* are unlikely to possess a general-purpose pattern-learning ability. However, information about the shape and size of objects necessary for some visually guided behaviours in *Drosophila* does pass through the sensory bottleneck. We feel that the general interest in visual coding, visually guided behaviour, biomimetics and in *Drosophila* neuroscience means that this paper is of general interest for your readership.

We take as our starting point the work of Seelig and Jayaraman (“Feature detection and orientation tuning in the Drosophila central complex.” *Nature*, 2013) who mapped the receptive fields properties of two groups of cells in the ellipsoid body of the central complex of *Drosophila*. Intriguingly, in contrast to mammalian simple cells, the receptive fields of these cells are very large (up to 90˚ in both elevation and azimuth) and the cell populations are very small in number (14 and 7 per eye for the two cell types). It is thought that sub-populations of these neurons serve pattern recognition and short-term memory for a bar’s location, respectively following classic behavioural experiments with flies. These abilities are lost when specific sub-populations of neurons are silenced. Our simulations reproduce fly performance and can even explain the surprisingly poor performance of *Drosophila* in discriminating some particular shape-pairs. However, crucially we show that pattern-learning performance can be improved easily through the addition of extra neurons, suggesting that this system might not be optimised through evolution for pattern recognition per se.

To consider more generally what information is preserved by these small networks of visually responsive neurons, we used artificial neural networks to ask how easy it is to decode more general information about stimulus shape from neural outputs. We show that these neurons are well-suited for encoding information about size, position and orientation, which are more relevant behavioural parameters for a fly than abstract pattern properties. Rather, the limited ability to discriminate patterns using abstract properties may well be a by-product arising from a simple visual system tuned to provide information to guide specific behaviours.

This leads us to suggest that in order to understand the properties of neural systems, one must consider how perceptual circuits put information at the service of behaviour, rather than whether, or how, they preserve all of the detail in a visual scene. This work thus presents novel insights into the function of visual circuits in *Drosophila*, but also has broader implications for neural coding in other systems.

In recent times, PLoS Computational Biology has a track record of high impact publications in a range of topics in invertebrate visual neuroscience (e.g. Visual learning for navigation: Ardin et al. (2016) and Baddeley et al. (2012); Pattern recognition in bees: Roper and Chittka (2017)). Therefore, because of both the theme and the general interest of this work, we feel very strongly that PLoS Computational Biology is its ideal location. This manuscript has not been submitted to any other journal previously.

Yours Faithfully,



Dr Paul Graham

(On behalf of Dr Andrew Philippides, Dr Alex Dewar and Dr Antoine Wystrach)