Numerical preference in a model of salamander visual salience

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The experimental results of Uller et al. (2003) suggest that salamanders tend to select the greater number of visually attractive stimuli when that number is less than 4. Based on these results, salamanders have been included among the animals who show sensitivity to "the number of items in a set" (Ansari, 2008). However, the neural basis of this apparent preference is an open question. Our simulation results support a different hypothesis: salamanders' apparent numerical preferences emerge from low-level vision. No number sense, or neural representation of integer numbers, is needed to obtain these results.

In simulation, we have successfully controlled a salamander's walking and swimming with a model of visual steering that reduces the salamander's 2-D retinal images to a 1-D saliency map, which is then further reduced to just 2 scalar neural control signals descending to the spinal cord. The spinal chord is modeled as interconnected bilateral central pattern generators (CPGs) controlling the body and limbs (Ijspeert, 2001). The salamander moves in an OpenGL computer graphics world.

Uller's experiments were inspired by 2 alternative forced choice experiments in higher vertebrates. The visual stimuli consisted of 2 narrow tubes of fruit flies, one to the salamander's left and the other to the right. We have reproduced this protocol in simulation.

Our results are sensitive to the surround inhibition strength in the classical receptive field (RF) in our RGC model. Our investigation included 2 different weak surround conditions to control for possible effects of differing overlap of neighboring central excitatory RFs. Uller's results were reproduced in the strong surround condition. Numerical discrimination was improved, beyond the salamander capabilities indicated in Uller's experiments, in the weak surround cases.

We also found that the simulation results are sensitive to stimuli speed and apparent size. Equalizing the total speed of the two groups abolished the preference for the more numerous group. Likewise, equalizing the total projection surface area also abolished the integer preference.

We have further found that the results are sensitive to stimulus configuration. In runs in which the tube lengths were halved or doubled, the simulations produced discrimination with quantities (6 vs. 4) that salamanders did not distinguish in Uller's experiments.

This suggests that Uller's results of may arise from intrinsic properties of the visual system, rather than as a schema of preferences for specific integral numbers of prey items. The salamander's visual system may be more tuned for successfully snapping at prey in the terminal phase of the hunt than for foraging – the foraging neural system may operate within very tight constraints, with numerical preferences evident in carefully controlled laboratory experiments as emergent properties rather than primary preferences.