A neural circuit for visual information spreading

Gregory Francis
Purdue University

A common description of visual processing is that information (such as brightness, color, or attention) spreads across retinotopic coordinates. At various levels of detail, such spreading has been proposed as an explanation for how brightness computations at luminance edges spread across surfaces (e.g., Grossberg & Mingolla, 1985), how color can leak from edges to fill-in surfaces (e.g., the water-color illusion, Pinna, 1987), how attention can spread within an object or across a group (e.g., Egly, Driver & Rafal, 1994) or surface (e.g., Tse, 2005), and why visual stimuli fade under induced scene fading (Francis & Kim, 2012) or contour erasure (Francis, 2015); similar mechanisms seem to be related to various properties of visual afterimages (Francis & Rothmayer, 2003; Kim & Francis, 2011).

At a descriptive level of modeling, it is common to suppose that whatever computational properties are required for such information spreading simply exist, and no effort is made to describe how such spreading would occur or would be appropriately constrained to stay within a group, surface, or object. The necessary computations are, in fact, rather challenging because the underlying circuits need to enable spreading of information to nearby neighbors in same cases and prevent such spreading in other cases. Past efforts to devise neural circuits that spread information include a hypothetical syncytium of closely connected neurons whose synapses can be modulated by neurotransmitters from other neurons (e.g., Grossberg & Mingolla, 1985) that thereby control the extent of information spreading. Such an approach has only modest neurophysiological plausibility, and simulations of the circuits reveal that the spreading of information tends to be quite slow and requires unrealistic parameter values.

Here, I describe a neural circuit made of integrate-and-fire neurons that instantiates a mechanism for the spreading of visual information. The circuit is simple and operates at a reasonable time scale with reasonable parameter values. Slight alterations to the anatomy allow the circuit to spread information across surfaces (constrained by the surface boundaries) as for brightness and color effects or across a group/object (as for some attention effects).

Given the ubiquity of the idea that information spreads across visual space, the neural circuit described here may have applications for many different models.