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Visual cortex as a depth computer: Grossberg's LAMINART or how we see the world in depth

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The laminar structure of cortex was first described by Ramón y Cajal (1899). It consists of six different layers, each containing a characteristic distribution of neurons and cell types connecting with other cortical and sub-cortical regions. These extensive connections form microcircuits that group into functionally distinct columns (e.g. Mountcastle, 1997). To account for the Venetian Blind Effect, Cao and Grossberg here propose a model which exploits the functional organization of visual cortex, in particular the selective firing activities of visual cortical neurons responding to the orientation and/or the luminance contrast of surface boundaries, demonstrated first by Hubel & Wiesel (1959 and 1962). Orientation selective neurons in visual cortex belong to an array of orientation columns which, combined with the eye of origin, provide a basic representation for visual information processing. The resulting hypercolumns are not functionally independent, but display long-range horizontal functional interactions, generating a seemingly infinite number of possibilities for information processing.

Cao and Grossberg's approach exploits these possibilities by suggesting a computational model architecture where selective cortical signals, activated by boundaries and the luminance contrasts which fill in the surfaces they delineate, control what the authors call three-dimensional surface capture. Rather than looking for some unique binocular matching rule to account for the effect considered here (the Venetian blind effect), they suggest a cortical disparity filter, which combines both monocular and binocular information to generate visual depth. On the basis of combined monocular and binocular input, the filter selectively activates the most pertinent perceptual groupings for generating the most likely depth percepts. It suppresses other, less likely but possible, groupings, and the winner takes all in this race for structural meaning, where cooperative and competitive interactions determine the relative synaptic weights of the different ongoing processes.

Three-dimensional surface depth is thus predicted to be a result of complex, facilitating and suppressing, layer-to-layer neural interactions. The mechanistic dynamics of this model have the functional advantage of being closely linked to physiological evidence for long-range feed-back interactions almost everywhere in cortex, and in particular in the visual cortex (see the references provided by the authors). Such interactions imply that any explanation of a complex perceptual phenomenon in terms of a single process or mechanism is unlikely. As a consequence, the model by Cao and Grossberg works out how monocular input is taken into account in the computation of visual depth at the cortical levels and delivers a complex yet highly plausible functional assumption for monocular depth effects. Monocular cues to pictorial depth, sometimes called monocular depth effects, have been listed by Leonardo da Vinci in his *Trattato della Pittura* well before they were measured psychophysically by visual scientists. Luminance contrast, relative size, and relative height in the visual field are three such cues, and any of them is self-sufficient in determining what

humans may perceive as nearer or further away in a visual image (Dresp, 1997; O'Shea *et al*, 1994, Guibal and Dresp, 2004, and Dresp-Langley and Reeves, 2013, for a review).

Monocular processing is essential for understanding the mechanisms that allow one-eyed individuals to see depth. Results of recent psychophysical research lead to suggest that the role of monocular vision in depth perception is, indeed, far more important than previously considered (Vishwanathan and Hibbard, 2013). Finally, by exploiting the laminar functional organization of visual cortex to account for how we see the Venetian Blind Effect (and other phenomena) reconnects visual science with an important aspect of brain evolution. Laminar functional organization of cortex is found in various species and it is likely to have evolved as a result of pressure on the brain's functional anatomy to adapt to constantly changing, visual and other, environments. Seeing in depth is even more relevant to animals as than it is to humans. Animal color vision in particular, which is equipped with anatomical and functional properties beyond those of human perception, plays an important part in how the different species perceive three-dimensional biological reality (e.g. Nolan, Dobson, Dresp and Jouventin, 2006). Many of the phenomena accounted for by Cao and Grossberg's model have been discussed previously in terms of hypotheses relative to the adaptive function of visual processing, as for example the illusory contours seen in the Kanzisa square (e.g. see Dresp, 1997, for a review), which the authors here repeatedly use to illustrate some of their model assumptions for the Venetian Blind Effect.

References

- Y. Cao and S. Grossberg (2014) How the venetian blind percept emerges from the laminar cortical dynamics of 3D vision. *Frontiers in Psychology*, doi: 10.3389/fpsyg.2014.00694.
- B. Dresp (1997) On illusory contours and their functional significance. *Current Psychology of Cognition*, **16**, 489-518.
- B. Dresp-Langley and A. Reeves (2013) Color and figure-ground: From signals to *qualia*. In S Magnussen, M Greenlee, J Werner, A Geremek (Eds.) *Perception Beyond Gestalt: Progress in Vision Research*. Psychology Press (Taylor & Francis), Abingdon UK, pp. **159-171**.
- C. R. C. Guibal and B. Dresp (2004) Interaction of color and geometric cues in depth perception: When does "red" mean "near"? *Psychological Research*, **10**, 167-178.
- D. H. Hubel and T. N. Wiesel (1959) Receptive fields of single neurons in the cat's striate cortex. *The Journal of Physiology*, **148**(3), 574-591.
- D. H. Hubel and T. N. Wiesel (1962) Receptive fields, binocular interaction, and functional architecture in the cat's visual cortex. *The Journal of Physiology*, **160**(1), 106-154.
- V. Mountcastle (1997) The columnar organization of the neocortex. *Brain*, **120**(4), 701-722.
- P.M. Nolan, F. S. Dobson, B. Dresp and P. Jouventin (2006) Immunocompetence is signalled by ornamental color in King Penguins, *Aptenodytes Patagonicus*. *Evolutionary Ecology Research*, **8**, 1335-1332.

R. P. O'Shea, S. G. Blackburn and H. Ono (1994) Contrast as a depth cue. *Vision Research*, **34**, 1595–1604.

S. Ramón y Cajal (1899) *Comparative study of the sensory areas of the human cortex*. Harvard University.

D. Vishwanathan and P. B. Hibbard (2013) Seeing in 3D with just one eye. *Psychological Science*, **24**, 1673-1685.