The art of seeing and painting

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Abstract—The human urge to represent the three-dimensional world using two-dimensional pictorial representations dates back at least to Paleolithic times. Artists from ancient to modern times have struggled to understand how a few contours or color patches on a flat surface can induce mental representations of a three-dimensional scene. This article summarizes some of the recent breakthroughs in scientifically understanding how the brain sees that shed light on these struggles. These breakthroughs illustrate how various artists have intuitively understood paradoxical properties about how the brain sees, and have used that understanding to create great art. These paradoxical properties arise from how the brain forms the units of conscious visual perception; namely, representations of three-dimensional boundaries and surfaces. Boundaries and surfaces are computed in parallel cortical processing streams that obey computationally complementary properties. These streams interact at multiple levels to overcome their complementary weaknesses and to transform their complementary properties into consistent percepts. The article describes how properties of complementary consistency have guided the creation of many great works of art.

Keywords: Complementary computing; visual cortex; perceptual grouping; surface filling-in; figure–ground perception; amodal boundaries; perspective; T-junctions; opponent colors; neon color spreading; watercolor illusion; chiaroscuro; complementary consistency; Impressionism; Fauvism; Matisse; Monet; Hawthorne; Hensche; Leonardo da Vinci.

1. INTRODUCTION

Many painters have struggled to understand how we see a 3D world, and to express their insights on flat canvases or other 2D surfaces. Cavanagh (2005) has noted that ‘discrepancies between the real world and the world depicted by artists reveal as much about the brain within us as the artist reveals about the world around us’ (p. 307). This article will summarize how the insights of various artists reflect different organizational principles about how the brain sees. The article does not, however, focus on discrepancies between the real world and the world depicted
by artists. Rather, I summarize brain organizational principles and mechanisms that reflect different artistic efforts. A recent cortical model of how the brain sees clarifies these organizational principles and mechanisms and enables the nature of artists’ struggles to be clearly articulated.

The foundational model is called the FACADE model, or Form-And-Color-And-DEpth model, of 3D vision and figure–ground perception (Grossberg, 1987b, 1994, 1997; Grossberg and McLoughlin, 1997; Grossberg and Pessoa, 1998; Kelly and Grossberg, 2000; McLoughlin and Grossberg, 1998). More recently, the FACADE model has been further developed as the 3D LAMINART model to show how the layered circuits of visual cortex realize processes of 3D vision and figure–ground perception, and to thereby explain and predict even more perceptual and brain data (Cao and Grossberg, 2005; Grossberg, 1999; Grossberg and Howe, 2003; Grossberg and Swaminathan, 2004; Grossberg and Yazdanbakhsh, 2005).

My discussion will address aspects of the following basic question that needs to be answered whenever one considers painting: Why can brain designs that represent the 3D world of our daily experience also respond to 2D pictures with conscious 3D representations of what the pictures depict? Without this brain capacity, the world of pictorial art, whether expressed by paintings, movies, or TV, could not exist. This is a huge topic, and I will only sample some highlights here. Before turning to artistic examples, I will ground my discussion with some basic discoveries from the FACADE and 3D LAMINART models about how the brain sees.

2. COMPLEMENTARY COMPUTING OF BOUNDARIES AND SURFACES

What are the perceptual units that are used by the brain to build visible percepts? Our modeling work predicted in the mid-1980s (Cohen and Grossberg, 1984; Grossberg, 1984; Grossberg and Mingolla, 1985a, 1985b; Grossberg and Todorovic, 1988), and many subsequent experiments have supported, the claim that boundaries and surfaces are the brain’s perceptual units, notably 3D boundaries and surfaces. Although this seems like a simple enough answer, actually it represented a radical break with previous views of visual perception.

This was a radical break because it is part of a major paradigm shift in understanding how the brain works. It also introduced into vision some conclusions which seem shocking to the non-specialist, because the properties of boundaries and surfaces are far from obvious. These shocking conclusions reflect, moreover, just the sorts of issues with which artists have had to cope to make great paintings.

The new paradigm is what I have called complementary computing (Grossberg, 2000). Complementary computing contradicts the previously popular hypothesis that the brain sees by using independent modules. The notion of independent modules tried to deal with the realization that visual properties (e.g. form, color, motion, depth) require specialized processes to be computed. Many scientists therefore proposed that our brains possess independent modules, as in a digital computer, to process these different properties. The brain’s organization into