Special Issue Introduction

Perceptual organization and neural computation

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Our present understanding of perceptual organization has its roots in the observations and qualitative principles of the Gestalt psychologists. Gestaltists and their associates identified and classified phenomena that reflect how perceptual systems derive representations of the environment based on fragmentary information and stimulus context. A broad range of phenomena was explored in this early work. The perceptual organization of visual motion was a major focus, involving both simple (Korte, 1915; Ternus, 1936; von Schiller, 1933; Wertheimer, 1912) and complex (Duncker, 1929; Musatti, 1924; Rubin, 1927; Wallach, 1935) motion patterns. The perceptual organization of static form was explored in studies of part–whole relationships in simple planar figures (Rubin, 1915; Wertheimer, 1923/1938) and later in studies of illusory contours and amodal completion (Kanizsa, 1955; Michotte, Thinès, & Crabbé, 1964). Additional topics included lightness and color phenomena (Benary, 1924; Gelb, 1929; Katz, 1935; Wallach, 1948) and the perception of events (Michotte, 1941). In brief, the research areas addressed by the first generations of Gestalt psychologists spanned much of what is now vision science. The broad impact of Gestalt ideas is reflected in the exceptional scope of this special issue.

This early work provides a rich source of observations and intuitions about mechanisms underlying various aspects of perceptual organization. Building on this foundation, current work is revolutionizing our understanding of perceptual organization in two respects.

First, the qualitative observations and descriptions generated by early work are now replaced by rigorous computational theories. This advance can be traced through a number of developments. Hochberg's and Attneave's commitment to quantitative characterization of perceptual phenomena (Attneave, 1954, 1959; Hochberg & McAlister, 1953; Hochberg & Silverstein, 1956) have inspired a generation of more rigorous psychophysical approaches to spatial (e.g., Feldman 1997; Field, Hayes, & Hess, 1993; Kubovy, Holcombe, & Wagemans, 1998; Oyama, 1961; Pizlo, Salach-Golyska, & Rosenfeld, 1997) and spatiotemporal (e.g., Adelson & Movshon, 1982; Burt & Sperling, 1981; Gepshtein & Kubovy, 2000, 2007; Ullman, 1979) perceptual organization. Brunswik's early and, at the time, radical ideas about the "ecological validity" of perceptual organization (Brunswik & Kamiya, 1953) led to contemporary Bayesian models of perceptual organization grounded in the statistics of our visual environment (e.g., Elder & Goldberg, 2002; Geisler, Perry, Super, & Gallogly, 2001; Martin, Fowlkes, Tal, & Malik, 2001). Theory and technique from the computer vision community have provided candidate algorithms and computational frameworks that are being tested as models of perception (e.g., Lee & Mumford, 2003; Lowe, 1985; Roberts, 1965; Tu & Zhu, 2002; Witkin & Tenenbaum, 1983; Zucker, Hummel, & Rosenfeld, 1977). Researchers have sought organizational principles that could explain perceived surface lightness and color (Adelson, 1993, 2000; Gilchrist, 2006; Gilchrist et al., 1999) and developed models based on the physics of light-surface interaction (Boyaci, Doerschner, Snyder, & Maloney, 2006) or the statistical structure of natural scenes (Brainard et al., 2006).

Second, direct recording from neurons in animals as well as imaging in human and non-human primates has begun to provide information about the neural mechanisms underlying key perceptual organization phenomena, including contour completion, contour salience, figure/ground perception, and a range of contextual effects (e.g., Albright & Stoner, 2002; Duncan, Albright, & Stoner, 2000; Gilbert & Wiesel, 1989; Lamme, 1995; Lee, Mumford, Romero,

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& Lamme, 1998; von der Heydt et al., 1984; Zhou, Friedman, & von der Heydt, 2000).

The goal of this special issue is thus to highlight new methodological and theoretical developments in visual psychophysics, visual neuroscience and computational vision, with a particular emphasis upon the computational and neural bases of these findings.

Consistent with the historically broad scope of perceptual organization research, this special issue concerns a broad range of visual phenomena: early visual coding, motion and event perception, contour integration, figure/ground perception, perception of 2D and 3D form, lightness and color perception, face and scene perception, attention and eye movements, audiovisual integration, and perceptual learning. Techniques also range broadly, from psychophysics to single-unit recording, fMRI, computational modeling and the statistical analysis of natural scenes. What binds these papers together, despite their broad scope over modalities and techniques, is a focus on the meaningful relational structure of the visual scene and the role of context on interpretation of stimulus information. Informed by the now classical work of the Gestalt psychologists, the authors of the work contained herein combine rigorous psychophysical techniques with the tools of mathematics, computational science, and neuroscience to recast our understanding of perceptual organization in terms of exacting quantitative theories.

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