Vision Research 50 (2010) 1503–1509

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Minireview

Statistical regularities in art: Relations with visual coding and perception

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ARTICLE INFO

Article history:
Received 11 August 2009
Received in revised form 3 May 2010

Keywords:
Vision
Perception
Natural scenes
Efficient coding
Art
Visual system
Statistical regularities
Retina
V1
Sparseness
Aesthetics

ABSTRACT

Since at least 1935, vision researchers have used art stimuli to test human response to complex scenes. This is sensible given the "inherent interestingness" of art and its relation to the natural visual world. The use of art stimuli has remained popular, especially in eye tracking studies. Moreover, stimuli in common use by vision scientists are inspired by the work of famous artists (e.g., Mondrians). Artworks are also popular in vision science as illustrations of a host of visual phenomena, such as depth cues and surface properties. However, until recently, there has been scant consideration of the spatial, luminance, and color statistics of artwork, and even less study of ways that regularities in such statistics could affect visual processing. Furthermore, the relationship between regularities in art images and those in natural scenes has received little or no attention. In the past few years, there has been a concerted effort to study statistical regularities in art as they relate to neural coding and visual perception, and art stimuli have begun to be studied in rigorous ways, as natural scenes have been. In this minireview, we summarize quantitative studies of links between regular statistics in artwork and processing in the visual stream. The results of these studies suggest that art is especially germane to understanding human visual coding and perception, and it therefore warrants wider study.

1. Introduction

Since art is designed for viewing by other humans, it is especially germane to vision science. Art represents a special class of images, and the analysis of visual art may be useful for understanding human vision. A similar proposal has been made for natural scenes. Over the past 20 years of natural scene research, it has become clear that natural scenes represent only a tiny fraction of all possible images and they contain a wealth of regular statistical structure. Notably, natural scenes contain higher-order redundancy not captured by most artificial stimuli (for a review, see Simoncelli & Olshausen, 2001). Recent research has demonstrated that the structure of natural scenes affects visual coding strategies in vertebrates and invertebrates. In other words, the visual system has adapted in evolution and ontogeny to efficiently process the natural scenes that surround individual organisms, through both shared and species-specific strategies. Visual art, in turn, is created through feedback with the artist's visual system, so that art images can be adapted to functions of human vision. Consequently, the study of art images and natural scenes—and relationships between the two—may result in important insights into the biology of the visual system.

In the present review, we will focus on regularities of spatial, luminance, and color statistics in art images. The central tenet of the present review is that regularities in art relate to basic functions of human perception. A host of studies through the history of modern vision science have employed art stimuli to study human visual system response (e.g., Buswell, 1935; Wooding, Mugglestone, Purdy, & Gale, 2002; Yarbus, 1967), perhaps because of the "inherent interestingness" (Hochberg, 1978) of such images. However, these studies have generally ignored the statistical regularities of such stimuli. The present paper is intended in part as an initial guide to these regularities.

The review is divided into two parts. First, we describe statistical regularities in artwork that appear related to low-level processing strategies in human vision, in particular to the processing of natural scenes (Section 2 – Part 1). Second, we describe variations in these statistics and how they have been tied to perceptual judgments and used to discriminate between different styles of art (Section 3 – Part 2).

2. Part 1. Statistical regularities in art

2.1. Pairwise spatial statistics

Converging evidence demonstrates that artworks show statistical regularities. A particular focus of recent research, mostly from our own groups, is the study of the Fourier spatial frequency power (or amplitude) spectra of visual art, which are equivalent to the pairwise (second-order) correlation statistics. Examples for the

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doi:10.1016/j.visres.2010.05.002

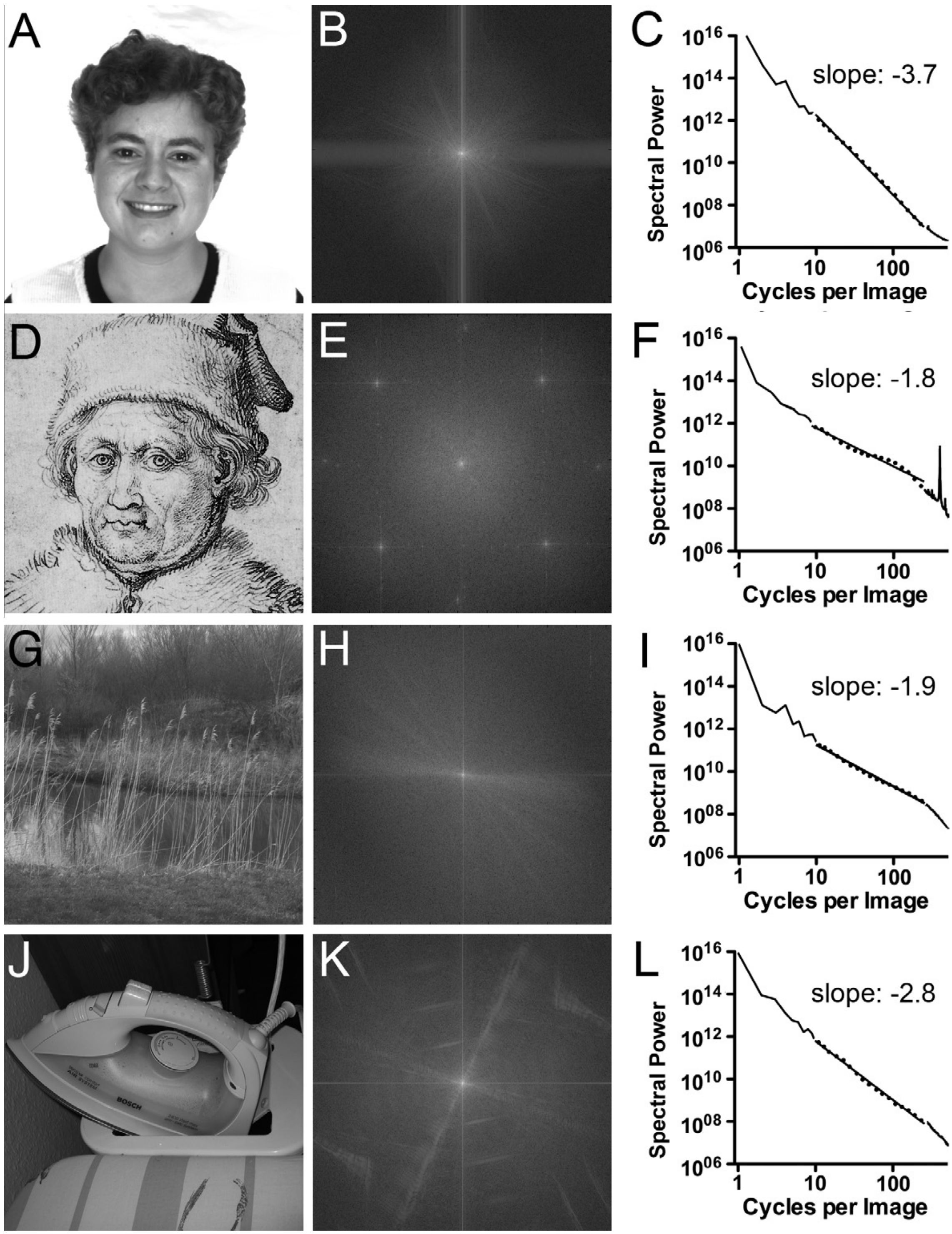

Fig. 1. (A) Original images (A, D, G, J), their Fourier power spectra (B, E, H, K) and log–log plots of radially averaged Fourier power versus spatial frequency (C, F, I, L). A–C. Example from the AR database of face photographs (Martinez & Benavente, 1998). D–F. Portrait (engraving) by the 15th century artist Martin Schongauer. G–I. Example from the Groningen database of natural scenes (Van Hateren & van der Schaaf, 1998). J–L. Photograph of a simple object (Redies, Hasenstein et al., 2007). In the Fourier spectra (B, E, H, K), the low spatial frequencies are represented at the center and lighter shades represent higher power. In the log–log plots (C, F, I, L), straight lines are fitted to binned data points between 10 and 256 cycles/image (Redies, Hänisch et al., 2007; Redies, Hasenstein et al., 2007). The slope of the line is given in each panel (see Table 1 for average values of each image category). The image shown in D is reproduced with permission from "Das Berliner Kupferstichkabinett", Akademischer Verlag, Berlin, 1994 (inventory number: 916-2; © Staatliche Museen zu Berlin, Kupferstichkabinett). The other images are reproduced with permission from the authors.

Fourier spectra of different categories of images are shown in Fig. 1B,E,H,K). The power spectrum measures the relative contribution of different spatial frequencies to the image as a whole. Evidence from neurophysiological studies suggests that the visual system contains frequency-specific response elements that perform a similar analysis at early stages of information processing (DeValois & DeValois, 1980).

In independent studies, Graham and Field (2007, 2008a), Redies, Hänisch, Blickhan, and Denzler (2007) and Redies, Hasenstein, and Denzler (2007) observed that, on average, the Fourier spectral