How to use individual differences to isolate functional organization, biology, and utility of visual functions; with illustrative proposals for stereopsis

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Abstract—This paper is a call for greater use of individual differences in the basic science of visual perception. Individual differences yield insights into visual perception’s functional organization, underlying biological/environmental mechanisms, and utility. I first explain the general approach advocated and where it comes from. Second, I describe five principles central to learning about the nature of visual perception through individual differences. Third, I elaborate on the use of individual differences to gain insights into the three areas mentioned above (function, biology/environment, utility), in each case describing the approach advocated, presenting model examples from the literature, and laying out illustrative research proposals for the case of stereopsis.

Keywords: Psychophysics; visual perception; vision; twin; factor analysis; utility; latent variable.

INTRODUCTION

This paper has two catalysts, one historical and one recent. The historical catalyst is the somewhat perplexing tendency in vision and other behavioral sciences to study natural and laboratory experiments separately. The advantage of combining such efforts is well-illustrated by the following quote from Cronbach’s classic paper, and American Psychological Association Presidential Address, ‘The two disciplines of scientific psychology’ (1957).

“The well-known virtue of the experimental method is that it brings situational variables under tight control. It thus permits rigorous tests of hypotheses and confident statements about causation. The correlational method, for its part, can study what man has not learned to control or can never hope to control.

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Nature has been experimenting since the beginning of time, with a boldness and complexity far beyond the resources of science. The correlator’s mission is to observe and organize the data from Nature’s experiments. As a minimum outcome, such correlations improve immediate decisions and guide experimentation. At the best, a Newton, a Lyell, or a Darwin can align the correlations into a substantial theory... both applied work and general scientific work... requires combined, not parallel, labors from [these] two historic disciplines”.

In other words, Nature’s experiments provide a rich source of information that can and should be exploited in combination with data from laboratory experiments. Indeed, since our theories must ultimately explain manipulations originating both inside and outside the laboratory, the traditional tendency in basic vision science to ignore the latter is scientifically perilous. I describe three basic vision science questions for which Nature’s experiments can yield particular insights: (1) What is the organization of a given visual function? (2) What biological and environmental mechanisms underlie that function? and (3) What is the utility of that function?

By Nature’s experiments, I mean the full range of natural variation in an ability as shaped by each individual’s unique genes and environment: individual differences. Methods based on individual differences have yielded substantial insight into the functional organization and genetic underpinnings of color vision (e.g. Neitz and Jacobs, 1986; Webster and Macleod, 1988); however, such methods have rarely been applied to other visual functions, particularly those that rely more heavily on processing beyond the retina like stereopsis, motion perception and object perception. The goal of this paper is thus to provide an open door for greater use of individual differences in basic vision science.

The proximal catalyst for this paper was the lively online discussion that inspired both the present ‘unresolved questions in stereopsis’ special issue and a symposium on individual differences that I ran at the 2007 Vision Sciences Society meeting. The discussion — on the 2,000-subscriber vision science email list Cvnet — followed my posted question, ‘What are the consequences of good and bad stereopsis?’. The 155 postings and direct responses I received indicated great interest in individual differences in stereopsis but little systematic data on them, and great interest in the underlying question, ‘What is the utility of stereopsis?’ but surprisingly little documented success in answering it (cf. Greenwald et al., 2005). The present paper, especially the section on ‘utility’, is largely a call to fill the gap highlighted by that discussion.

Two chief methodological traditions provide inspiration and a foundation for greater use of individual differences in basic vision science. One is cognitive neuroscience’s twin subfields of neuroimaging and patient-based cognitive neuropsychology. Neuroimaging has begun using individual differences to illuminate brain function by identifying aspects of brain activity that predict individual differences in behavior; however, despite initial successes (e.g. Epstein et al., 2005; Vogel and Machizawa, 2004; Yovel and Kanwisher, 2005) and burgeoning use in other con-