Studying Visual Function using Individual Differences: A Theoretical Framework and a Study of Motion Processing

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A Standard Question in Vision Sciences:

What is the systems architecture (i.e. overlap vs. independence of functions) in visual perception?

E.g. To what extent do motion perception and pursuit eye movements rely upon common underlying mechanisms?

A New Approach to Answering this Question, using Individual Differences Data:

To the extent that individual differences in one psychophysical measurement predict those on another - over and above any prediction for appropriate control tasks - this is evidence that these tasks rely on common underlying mechanisms.

The Assumptions Underlying the New Approach:

Two Standard Vision Science Assumptions...

- Universality - The functions being studied (and components thereof) exist in similar qualitative form across normal individuals.
- Modularity - Cognition consists of a number of independent processing units.

One Assumption *New* to Vision Science...

- *Ubiquitous Variation - The efficiencies of all functions being studied (and components thereof) vary measurably between normal individuals.*

The Goal of this Project:

Validate the utility of the individual differences approach, as well as the plausibility of the "ubiquitous variation" assumption (see above), while tackling the classic question:

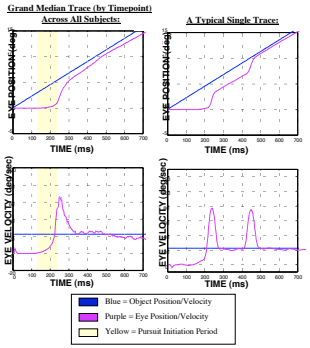
To what extent do motion perception and pursuit eye movement initiation rely upon common underlying mechanisms?

The Pursuit Initiation Task…

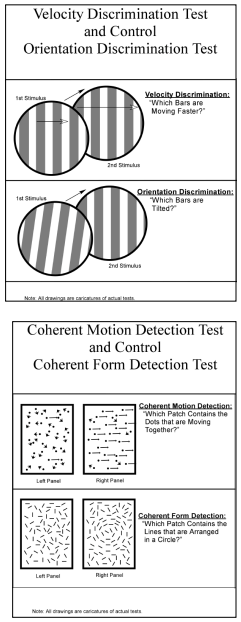
Instructions:

"A bar will appear in the center of the screen and zoom up, down, left, or right, off the screen. Please follow the bar with your eyes as quickly and accurately as you can."

Representative Position (top) and Velocity (bottom) Eye Traces...



The Psychophysical Tasks:



Results 1: Evidence for "Ubiquitous Variation"* in Each Task: Variation Between Individuals is Large Relative to Variation Within Individuals

Demonstrated by Acceptable Split-Half Reliability for All Tasks...

Velocity Discrimination:	r=0.82
Orientation Discrimination:	r=0.70
Coherent Motion Detection:	r=0.87
Coherent Form Detection:	r=0.55
Eye Tracking:	r=0.92

Note: All reliabilities are Spearman-Brown corrected. Variations in reliability between tasks are controlled for statistically in all subsequent analyses.

*See "The Assumptions…" above for an explication of the "Ubiquitous Variation" assumption.

Results 2: New Evidence that Motion Perception and Pursuit Initiation Rely upon Common Underlying Mechanisms: Specific Associations between Motion Tasks and Pursuit Initiation Velocity

Figure #1: Median Eye-Velocity Trace for Best-Performing (green) Half of Subjects on Each Psychophysical Motion Perception Task Shows Quicker Pursuit Initiation than that of Worst-Performing (orange) Half

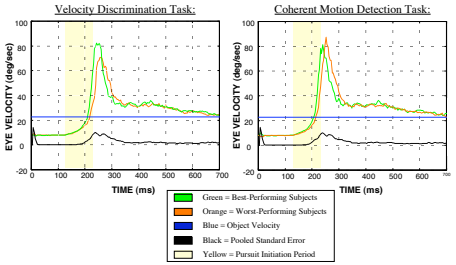
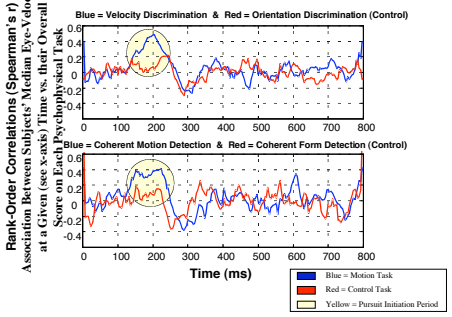


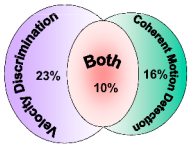
Figure #2: Specific Association Between Pursuit Initiation and Each Psychophysical Motion Perception Task Over and Above its Matched Control Task



Results 3: Do our two psychophysical motion tasks predict pursuit initiation jointly or independently?

Answer: More Variance Explained Independently (19%) than Jointly (10%)

Percent of Pursuit Initation Variance Explained By Motion Tasks:



Conclusions:

- We have isolated a single unique assumption necessary for using individual differences data to make inferences on systems architecture: the "ubiquitous variation" assumption.
- We have provided evidence that the "ubiquitous variation" assumption holds in the domains of both motion perception and pursuit initiation.
- We have used an "individual differences" approach to gather evidence that motion perception, generally-speaking, and pursuit initiation rely upon similar underlying mechanisms.
- We have provided evidence that pursuit initiation relies upon some underlying processes unique to the tasks of velocity discrimination and coherent motion detection respectively, as well as some (but fewer) processes common to both.

General benefits of the individual differences approach:

- Produces a quantitative, effect-size measurement of systems association that complements the qualitative, "yes/no" systems dissociations established through lesion-based cognitive neuropsychology.
- Gathers data usable in search for genetic bases of visual perception (e.g. Plomin & Kosslyn, Nat Neuro, 2001).
- May instruct us on the nature and consequences of naturally occurring differences in visual perception.
- Can validate psychophysical tests for clinical use.