Attentional and Nonattentional Processes in Vision: Implications for Display Design

CHI 2003 Tutorial

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Table of Contents

Agenda

18.00–18.15 Introduction
- Overview of tutorial
- How our intuitions about human vision can go wrong
- Demo: Change blindness

18.15–19.00 Rapid (Preattentive) Vision
- Experimental methodology: Visual search
- Capabilities of “rapid” visual intelligence
- Implications: Information visualization

19.00–19.30 Attentional Vision
- Experimental methodology: Change detection
- Nature of visual attention; attentional nexus
- Implications: Dynamic visual displays

19.30–19.45 Discussion

19.45–20.00 Break

20.00–20.45 Scene Perception
- Experimental methodology: Attentional distraction
- Virtual representation of scenes
- Implications: Coercive graphics; “magical” displays

20.45–21.15 Nonattentional Vision
- Experimental methodology: Eye movements; Mindsight
- Concurrent visual subsystems
- Implications: “Zombie” displays

21.15–21.30 Discussion

Course Overview

With the growing reliance on visual displays for many real-time operations, there is an increasing need for displays to be such that information pickup is:

- as rapid as possible (speed)
- as error-free as possible (accuracy)
- as effortless as possible (transparency)

Indeed, situations such as driving call for all three of these factors to be maximized simultaneously. How might this be done?

As technology advances, the limiting factor in the creation of highly effective, transparent displays will no longer be the production of the displays themselves, but rather, will be our ability to couple them effectively to the human visual system. Doing so will require sound knowledge of how human vision works.

Although aspects of human visual perception are often covered in HCI courses, these usually involve relatively basic faculties such as color or motion perception. Although these are important, there is usually little coverage of the large increase in knowledge about vision that has been achieved over the past 20 years. In particular, HCI practitioners often have little knowledge of how attentional (and nonattentional) visual process operate. This is unfortunate, since these processes are central to the way that humans interact with their world.

This course will attempt to remedy this situation by bringing researchers up to date on many of the latest discoveries (many of which involve rather large effects). It will also provide some discussion about how these new phenomena and theories can be used in the design of much more effective—and even novel—kinds of visual displays and interaction techniques. Among these are:

- Guidelines for an extended set of “basic” visual properties that can be used to attract attention or convey visual information. Although simple properties such as color and size are useful, more complex properties such as three-dimensional orientation can also be used.
- Guidelines for the design of displays that enable the rapid and accurate attentional pickup of information. Also discussed will be techniques for evaluating attentional “units” (which are the bases of these displays).
- Guidelines for the design of displays that convey information via dynamic means (e.g., movement patterns). This includes limits on what can be conveyed dynamically, as well the need to avoid attentional distraction.
- Tentative suggestions for the design of “coercive” graphics that momentarily control the attention of the user, resulting in displays that may be much easier to use and less error-prone than current systems.
- Tentative suggestions for the design of displays aimed at nonattentional aspects of visual perception—for example, displays that will allow a user to more easily and accurately move a mouse to a given location, even though nothing exceptional is consciously noticed.

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About the Instructor

Ronald A. Rensink is a professor at the University of British Columbia (UBC), with a joint appointment in the departments of Computer Science and Psychology. Ron obtained a PhD in Computer Science (computer vision) from UBC, and then spent two years as a postdoc in the Psychology department (Vision Sciences Lab) of Harvard University. Ron spent six years as a research scientist at Cambridge Basic Research, a lab sponsored by Nissan Motor Co., where he did research on attentional factors that could influence the design of automobile interfaces. In 2000, he returned to UBC, where he is now part of the Human-Computer Interaction Group, and works on issues related to interface transparency.

Ron has organized special sessions at several international conferences, including the 1997 meeting of the Association for Research in Vision and Ophthalmology (ARVO), and the 2001 European Conference on Eye Movements (ECEM). He is an experienced speaker, having given 18 invited talks over the past six years, and over 30 conference presentations. He has also given several workshops, the most recent being part of a day-long course on interface design at SIGGRAPH 2002.

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MAGIC

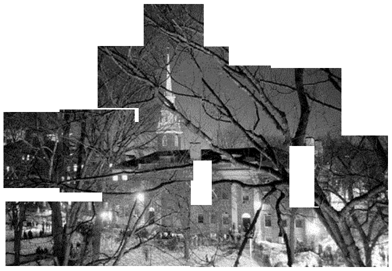
Overview

- **Introduction**
  - How our intuitions about human vision can go wrong
- **Rapid (Preattentive) Vision**
  - Capabilities of “rapid” visual intelligence
- **Attentional Vision**
  - Limits on visual attention
- **Scene Perception**
  - Virtual representation of scenes
- **Nonattentional Vision**
  - Concurrent visual subsystems

0. Introduction

How Do People See Scenes?

Intuition: ***Visual buffer accumulates information***

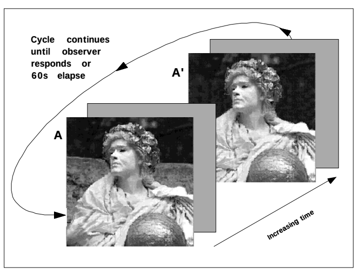


Because we accumulate detailed information, it's always easy to see changes...

But is this always true?

Make change during brief blank interval
between original and changed images

<u>Flicker paradigm</u> (Rensink et al., 1997)



Demo

Result: Changes made under these conditions are extremely difficult to notice, even when the changes are large, anticipated, and repeatedly made

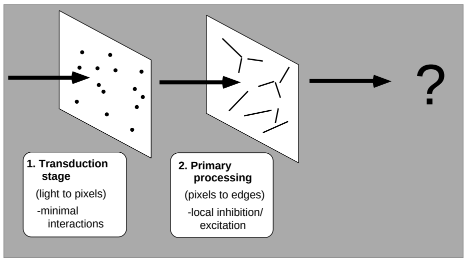
This is known as **<u>change blindness</u>** (Rensink et al, 1997)

So what's happening here?

- How does vision actually work?
- How can we take advantage of this for the design of effective visual displays?

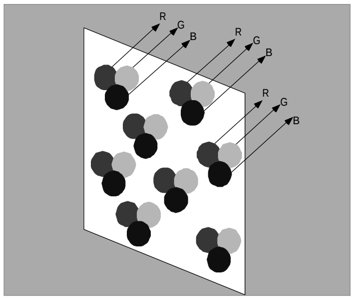
1. Rapid (Preattentive) Vision

Look first at initial stages of visual processing



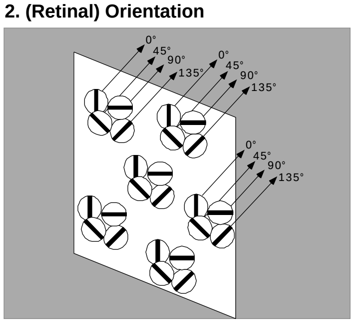
What properties are determined at this level?

1. (Retinal) Color



What properties are determined at this level?

2. (Retinal) Orientation



Summary - Vision Science

- complex properties (e.g., 3D orientation) can be determined rapidly and in parallel
- these are calculated via simple rules that work most of the time (e.g., lighting from above)

Old view: ~~To achieve its great speed, early vision sacrifices the **complexity** of the properties it determines.~~

New view: To achieve its great speed, early vision sacrifices the **reliability** of the properties it determines.

Summary - Implications for Display Design

Information Visualization

→ Displays need not be limited to simple 2D properties (e.g., color and orientation) to convey information. More complex properties can also be used.
- will only work under the appropriate conditions
- likely to be as effective as "old" dimensions

→ "Primitive" properties won't always work as expected.
- will be unavailable to rapid vision if pre-empted by proto-objects

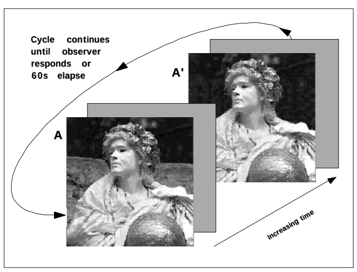
2. Attentional Vision

What is the role of visual attention?

Old view: Attention “welds” preattentive features into more complex structures.
The accumulation of these structures is then the basis for visual perception

But: 1) A lot of the “welding” is already done at the preattentive (rapid) level
2) If structures accumulate, why can we fail to see large changes (change blindness)?

Recap: change blindness is the failure to see changes in an image, even when these are large, and repeatedly made



Demo

Change blindness also occurs for changes made simultaneous with (see Rensink, 2002a)**:**

- image flicker
- eye movements (saccades)
- eyeblinks
- "splats" not on change
- movie cuts
- real-world interruptions
- gradual change

Demo

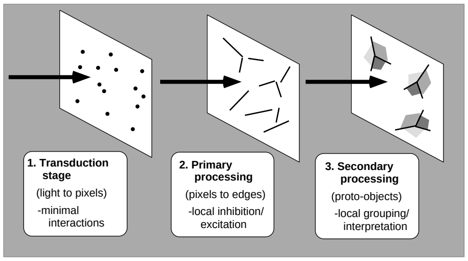
Proposal: All of these have the same cause

Proposal: Attention is needed to perceive change in an object.

Under normal circumstances, a change creates a motion transient, which draws attention.

When change is made same time as another event, transients interfere with drawing of attention, causing change to become “invisible”.

Recap: Initial stages of visual processing



Coherence theory

1

Without attention, proto-objects are volatile, i.e., have limited coherence in space and time. Thus, they are **replaced** by any new stimuli.

Summary - Implications for Display Design

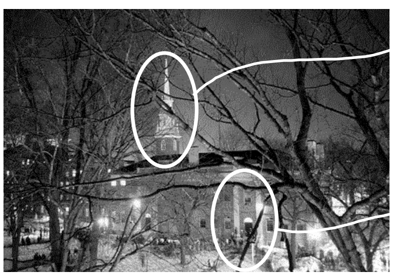
1. Pickup of Information

- optimally effective displays based on:
  - static aspects of visual perception (e.g. color)
  - dynamic aspects (e.g. attention management)

- what is attended depends on the **viewer** & the **task**
  - different people can literally see the same world very differently

  → can use flicker paradigm to measure which parts and properties of objects are attended first. (= most easily seen to change)

Rensink et al (1997)



Central Interest
-mentioned by most observers

Marginal Interest
-mentioned by no observers

Central interests are objects/regions perceived to be important (or at least interesting)

Marginal interests are objects/regions that are not

Average time for detecting change (Rensink et al., 1997):
- **Central interests: 4.7 seconds**
- **Marginal interests: 10.9 seconds**

(Marginal changes are on average > 20% larger in area)

Could adapt this to:
different viewers x different tasks x different conditions

4. Nonattentional Vision

Triadic architecture implies an important role for nonattentional streams in vision

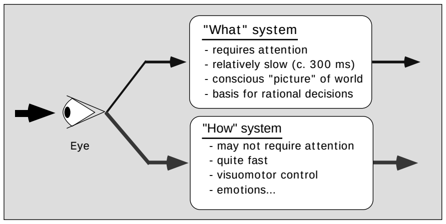
These streams are not primarily concerned with **explicit** (= conscious) perception
- this is done via attentional mechanisms

-> Mapped out via **implicit** (= unconscious) detection of change?

Implicit Detection of Change: Visuomotor

- Bridgeman et al. (1975) — **oculomotor response**
  - target moves while observer saccades to it
  - eye makes corrective saccade, even though observers have no explicit perception of change
- Goodale et al. (1986) — **manual pointing**
  - target moves while observer saccades to it
  - hand corrects its trajectory while reaching to target, even though observers have no explicit perception of change

Proposal: **Two visual subsystems** Milner & Goodale (1995)



Two subsystems (submodalities) are largely separate
- supported by two separate neural pathways

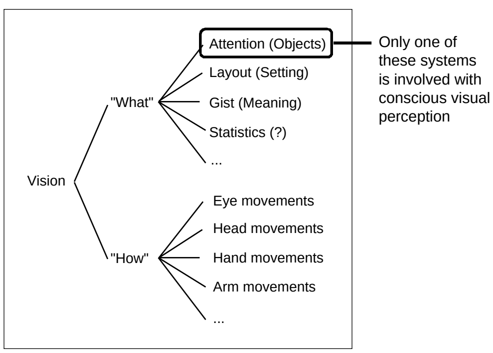
The “how” system is essentially an “inner zombie”

Summary - Vision Science

Vision appears to be carried out by a **set of subsystems**, each of which operates **concurrently**, and is largely **independent of others**

Primary division into
- "What" system: (conscious) visual perception
- "How" system: nonconscious visuomotor actions

Division of "What" system into
- Attentional system: object perception - conscious(?)
- Nonattentional system: visual context - nonconscious(?)



Summary - Implications for Display Design

Display might influence other aspects of user's experience besides conscious "image" of its contents

1. Visuomotor Actions

- displays designed for "zombie system":

→ could guide user actions (e.g. control of mouse)

→ avoid problems with lag for visual feedback
- pointing can be precise with open-loop control (Po, 2002)

→ might induce user to automatically "do the right thing" (no conscious noticing of this)

2. Displays for "Sixth Sense" Experience

- feeling that something is occurring, without an accompanying visual experience

→ use as a second form of "soft warning"
- increase user vigilance without disrupting normal attentional allocation during a task (e.g. when driving)