INFORMATION VISUALIZATION

Alvitta Ottley
Washington University in St. Louis
ANNOUNCEMENTS

• Assignments are all graded
• No more 2-week wait
• Academic integrity
MY EXPECTATIONS

- Try
- Be creative
- Participate
- Integrity
MY EXPECTATIONS

• Try
• Be creative
• Participate
• Integrity
  • Your work should be your own
ANNOUNCEMENTS

• Assignments are all graded
• No more 2-week wait
• Academic integrity
• Assignment 3 due tonight
• New assignment available
TODAY..

PERCEPTION: WHY WE SEE WHAT SEE
SELECTIVE ATTENTION

https://www.youtube.com/watch?v=vJG698U2Mvo
CHANGE
BLINDNESS
HOW DO WE SEE?
WE SEE 2.5D

We see a 2D image, but also depth associated with each “pixel”
Brain pixels vary enormously in size over the visual field. This reflects differing amounts of neural processing power devoted to different regions of visual space.

At the edge of the visual field we can only barely see something the size of a fist at arm’s length.

We can resolve about 100 points on the head of a pin held at arm’s length in the very center of the visual field called the fovea.

Over half of our visual processing power is concentrated in a slightly larger area called the parfovea.
EXAMINING THE MONA LISA

- (left): peripheral vision
- (center): near peripheral vision
- (right): central vision

Image source: Margaret Livingstone
The cornea and the lens form a compound lens to focus an image on the retina. The retina at the back of the eye contains light receptors that convert light into signals which travel up the optic nerve to the visual areas 1 and 2 at the back of the brain.

Eye muscles move the eyes rapidly to cause the fovea to be directed to different parts of the scene. Each optic nerve contains about a million fibers transmitting visual information from the retina to processing in visual area 1.

Visual signals are first processed here in visual area 1 (V1) at the back of the brain.
CONES AND RODS

• 100+ million receptors
• 120 million rods (for light)
• 6-7 million cones (for red (64%), green (32%), blue (2%))
COLOR-SENSITIVE CONES

- 100+ million receptors (cones and rods)
- 1 million optic nerves
Incoming information first arrives in visual area V1 at the back of the brain. The information then passes successively through V2 and V4 and then to the inferotemporal cortex (IT). The lateral occipital cortex (LOC) is involved in region finding. Signals from the prefrontal cortex are sent back to consolidate task-relevant patterns.

This is sometimes called the “what” pathway, as opposed to the “where” pathway. The what pathway has the function of identifying objects. The where pathway has more to do with visually guided actions.
• V1 (visual area 1) responds to color, shape, texture, motion, and stereoscopic depth.
• V2 (visual area 2) responds to more complex patterns based on V1
• V3 (visual area 3) responds to the what/where pathways, details uncertain
• V4 (visual area 4) responds to pattern processing
• Fusiform Gyrus responds to object processing
• Frontal Lobes responds to high-level attention
HOW DO WE SEE PATTERNS?
NEURON BINDING

- V1 identifies millions of fragmented pieces of information given an image

- The process of combining different features that will come to be identified as being parts of the same contour or region is called “binding”

- It turns out that neurons in V1 do not only respond to features, but also neighboring neurons that share similarities
  - When neighboring neurons share the same preference, they fire together in union
TYPES OF VISUAL PROCESSING

Features: are processed in parallel from every part of the visual field. Millions of features are processed simultaneously.

Patterns: are built out of features depending on attentional demands. Attentional tuning reinforces those most relevant.

Objects: most relevant to the task at hand are held in Visual Working Memory. Only between one and three are held at any instant. Objects have both non-visual and visual attributes.

Bottom-up information drives pattern building

Top-down attentional processes reinforce relevant information
**BOTTOM UP**

- The process of successively select and filter information so that:
  - Low level features are removed
  - Meaningful objects are identified
- Gestalt Psychology

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*When we see something, such as a dog, we do not simply form an image of that dog in our heads. Instead, the few features that we have directly fixated are bound together with the knowledge we have about dogs in general and this particular dog. Possible behaviors of the dog and actions we might take in response to it are also activated.*
TOP-DOWN

• Process driven by the need to accomplish some goal
  • Just-in-time visual querying

The sequence of eye movements made by someone making a peanut butter and jelly sandwich. The yellow circles show the eye fixations. (Image courtesy of Mary M. Hayhoe.)
EYE MOVEMENT PLANNING

• “Biased Competition”
  • If we are looking for tomatoes, then it is as if the following instructions are given to the perceptual system:
    • All red-sensitive cells in V1, you have permission to send more signals
    • All blue- and green-sensitive cells in V1, try to be quiet

• Similar mechanisms apply to the detection of orientation, size, motion, etc.
WHAT STANDS OUT == WHAT WE CAN BIAS FOR

- Experiment by Anne Treisman (1988)
  - Subjects were asked to look for the target (given an example image)
  - Subjects were briefly exposed to the target in a bed of distractors
  - Subjects were asked to press “yes” if the target exists, and “no” if it doesn’t
TREISMAN’S CRITICAL FINDING

• The critical finding of this experiment is that

“for certain combinations of targets and distractors, the time to respond does **NOT** depend on the number of distractors”

• Treisman claimed that such effects are measured called “pre-attentive”.
  • That is, they occurred because of automatic mechanisms operating prior to the action of attention and taking advantage of the parallel computing of features that occurs in V1 and V2
EXAMPLES

Pop-out effects depend on the relationship of a visual search target to the other objects that surround it. If that target is distinct in some feature channel of the primary visual cortex we can program an eye movement so that it becomes the center of fixation.

The green dot pops out

The oblique lines pop out

The large circle pops out

If two dots were to oscillate as shown they would pop out
“PRE-ATTENTIVE”

• The term “pre-attentive” processing is a bit of a misnomer
  • Follow-up experiments show that subjects had to be greatly focused (attentive) in order to see all but the most blatant targets (exceptions: a bright flashing light for example).
  • Had the subjects been told to not pay attention, they could not identify the features in the previous examples
MORE SPECIFICALLY

- A better term might be “tunable” to indicate the visual properties that can be used in the planning of the next eye movement

- Strong pop-up effects can be seen in a single eye fixation (one move) in less than 1/10 of a second

- Weak pop-up effects can take several eye movements, with each eye movement costing 1/3 of a second
“TUNABLE” FEATURES

• Can be thought of as “distinctiveness” of the feature

• It is the degree of feature-level “contrast” between an object and its surroundings.
  • Well known ones: color, orientation, size, motion, stereoscopic depth
  • Mysterious ones: convexity and concavity of contours (no specific neurons found that correspond to these)

• Neurons in V1 that correspond to these features can be used to plan eye movements
VISUAL CONJUNCTIVE SEARCH

• Finding a target based on two features (green and square) is known as visual conjunctive search
  • They are mostly hard to see
  • Few neurons correspond to complex conjunction patterns
  • These neurons are farther up the “what” pathway
  • These neurons cannot be used to plan eye movements
difficult
easy

The inverted T has the same feature set as the right-side-up T and is difficult to see. But the bold T does support pop-out and is easy to find.
Similarly the backwards L has the same feature set as the other items, making it difficult to find. But the green triangle addition does pop out.
A color that is close to many other similarly colored dots cannot be tuned for and is difficult to find.
Similarly, if a line is surrounded by other lines of various similar orientations it will not stand out.
Questions?
DEGREE OF “CONTRAST”

• For pop-up effects to occur, it is not enough that low-level feature differences exist

• They must also be sufficiently large

• For example, for the orientation feature, a rule of thumb is that the distractors have to be at least 30 degrees different

• In addition, the “variations” in the distractors (backgrounds) also matter.
  • For example, for the color feature, the tasks are different if there are two colors vs. a gradient of colors used in the test
FEATURE SPACE DIAGRAM
MOTION

• Our visual system is particularly tuned to motion (perhaps to avoid predators)

• Physiologically, motion elicits one of the strongest “orientation response”
  • That is, it is hard to resist looking at something that moves
MOTION

- Study by Hillstrom (1994) shows that the strongest orientation response does not come from simple motion,
- But objects that emerge into our visual field
MOTION

• Because a user cannot ignore motion, this feature can be both powerful and irritating spin
• In particular, high frequency rapid motions are worse than gradual changes (trees sway, clouds move – these are not irritating)
Questions?
DESIGN IMPLICATIONS
DESIGN IMPLICATIONS

• If you want to make something easy to find, make it different from its surroundings according to some primary visual channel

• For complex datasets, use multiple parallel channels. In V1, these features are detected separately and in parallel (color, motion, size, orientation, etc.)
DESIGN IMPLICATIONS

- The channels are additive.
  - Double-encode the same variable with multiple features to ensure multiple sets
VISIBILITY ENHANCEMENTS NOT SYMMETRIC

- Adding pops, subtraction (most often) does not
A set of symbols designed so that each would be independently searchable. Each symbol differs from the others on several channels. For example, there is only one green symbol; it is the only one with oblique lines and it is the only one with no sharp edges.
INTERFERENCE

• The flip side of visual distinctiveness is visual interference.

Text on a background containing similar feature elements will be very difficult to read even though the background color is different.

The more the background differs in element granularity, in feature similarity, and in the overall contrast, the easier the text will be to read.

Subtle, low-contrast background texture with little feature similarity will interfere less.
PATTERNS, CHANNELS, AND ATTENTION

• Attentional tuning operates at the feature level (not the level of patterns).

• However, since patterns are made up of features, we can choose to attend to particular patterns if the basic features in the patterns are different.
SELECTIVE ATTENTION

Feature level tuning can allow us to attend to different layers of information.
ARE THESE LEARNABLE?
Unfortunately, feature detection is “hard-wired” in the neurons and cannot be learned...
PATTERN LEARNING

• V1, V2 are too low level. They (mostly) cannot be trained
  • In other words, they are universals
  • However, if you grow up in NYC, you will have more neurons responding to vertical edges

• V4 and IT can be trained
  • Babies learn better than adults
  • For example, speed reading is learnable
OTHER WAYS TO HACK THE BRAIN - PRIMING
PRIMING INFLUENCES... CREATIVITY

Enter as many unique and unusual uses as possible for a QUARTER (the coin).
(Minimum: 10)

1. 
2. 
3. 
4. 
5. 

High creativity

Low creativity
PRIMING INFLUENCES... VISUAL JUDGMENT
PRIMING INFLUENCES... ANALYSIS PATTERNS
Questions?
NEXT TIME...

Read paper!
Grids and hovering with d3