Texture and Glyphs

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Goal For Last Week and This

- Understand display and perception
  - What the human visual system can perceive
    - In terms of color, patterns, etc.
    - Based on the structure of the eye and the processing within the brain
  - What is possible to display/see/understand
    - Can influence how we design visualizations
  - Today we will discuss texture and glyphs
- Much of the material drawn from Ware chapters 2-6.

Eye Motion

- Eye generally moves quickly between fixation points as you look at something
  - Motions are called saccades
  - 2-5 saccades per second (200-500ms per fixation point)
  - Fixation points can vary – e.g. move left to right as you read
  - Typically about 2 degrees (e.g. reading) to 5 degrees (e.g. scanning a scene)
  - Keeping key display close limits motion time, which allows better viewing

Vision and Visual Search

- Eye will tend to move to “next” thing (typically in near periphery from fovea) to match some pattern.
- Early visual system tends to identify certain common visual features – directional contours, blobs of sizes, colors, etc.
- Cognitive processes seem to give higher “weight” to the thing being visually sought
  - Give more or less response to certain low-level features in how they affect higher level features
  - And can adapt to different types of scenes – allow “getting used to” a particular visualization

Visual System

- Retina: Cones feed into Ganglion cells that form receptive fields
  - Concentric fields with on/off in center/surrounding
  - Also split color into Red-Green, Blue-Yellow, Black-White information
- Signals from optic nerve (about 2 million) arrive in Visual Area 1 (V1); V1 proceses and sends to Visual Area 2 (V2)
  - V1 + V2: Billions of neurons, over 40% of visual processing

Visual System

- V1 and V2 process entire visual field in parallel
- They identify key local features of form
  - Orientation
  - Size
  - Color
  - Depth
  - Motion
- Channel theory states that these different low-level processing systems allow targeting of different visual “channels”
  - There are also auditory channels

Visual Channels

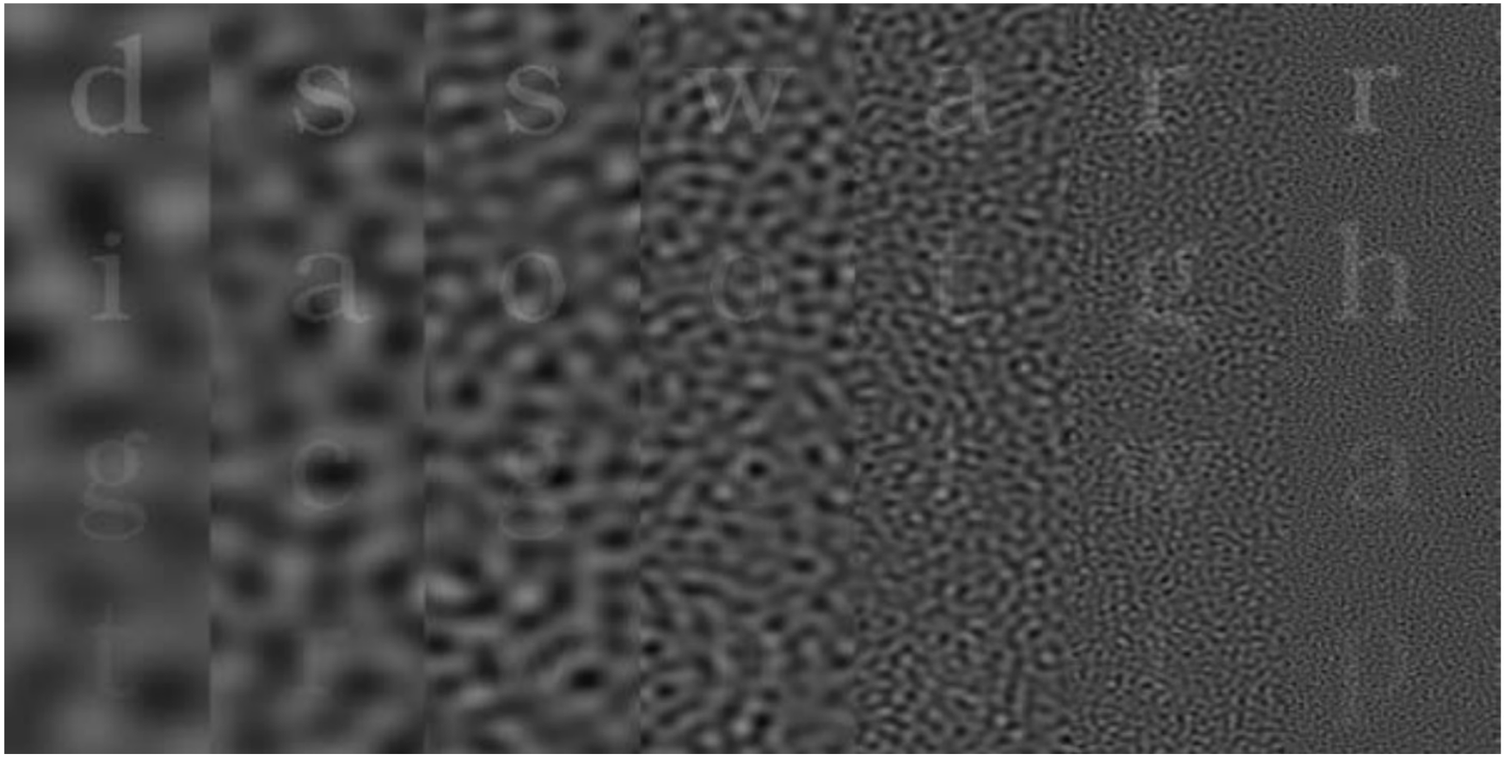
- 3 main channels, subdivided into smaller channels
  - Color
    - Luminance (also is key to the 2 other main channels)
    - Red-Green
    - Blue-Yellow
  - Form and Texture
    - Spatial Frequency
    - Orientation
  - Motion
    - Direction
    - Phase
- Information on different channels can be processed separately
  - Can concentrate on one or the other
  - But, info on same channel can be fused, but not really separated

Texture

- Form and texture: can perceive differences in spatial frequency and orientation
  - About 4 spatial frequency channels (i.e. the scale of a texture pattern)
  - Orientations need to vary by 30 degrees or more for low level processing
    - Higher level processing can resolve finer differences in orientation (as well as other channels)
  - Could allow different information to be transmitted even across differing textures, though they are not fully independent
- Note: receptive fields seem to follow a Gabor function, and there is significant work on how this perception allows detection of various features

Spatial Frequency

- Encode different information at different frequencies, or it won't be very visible

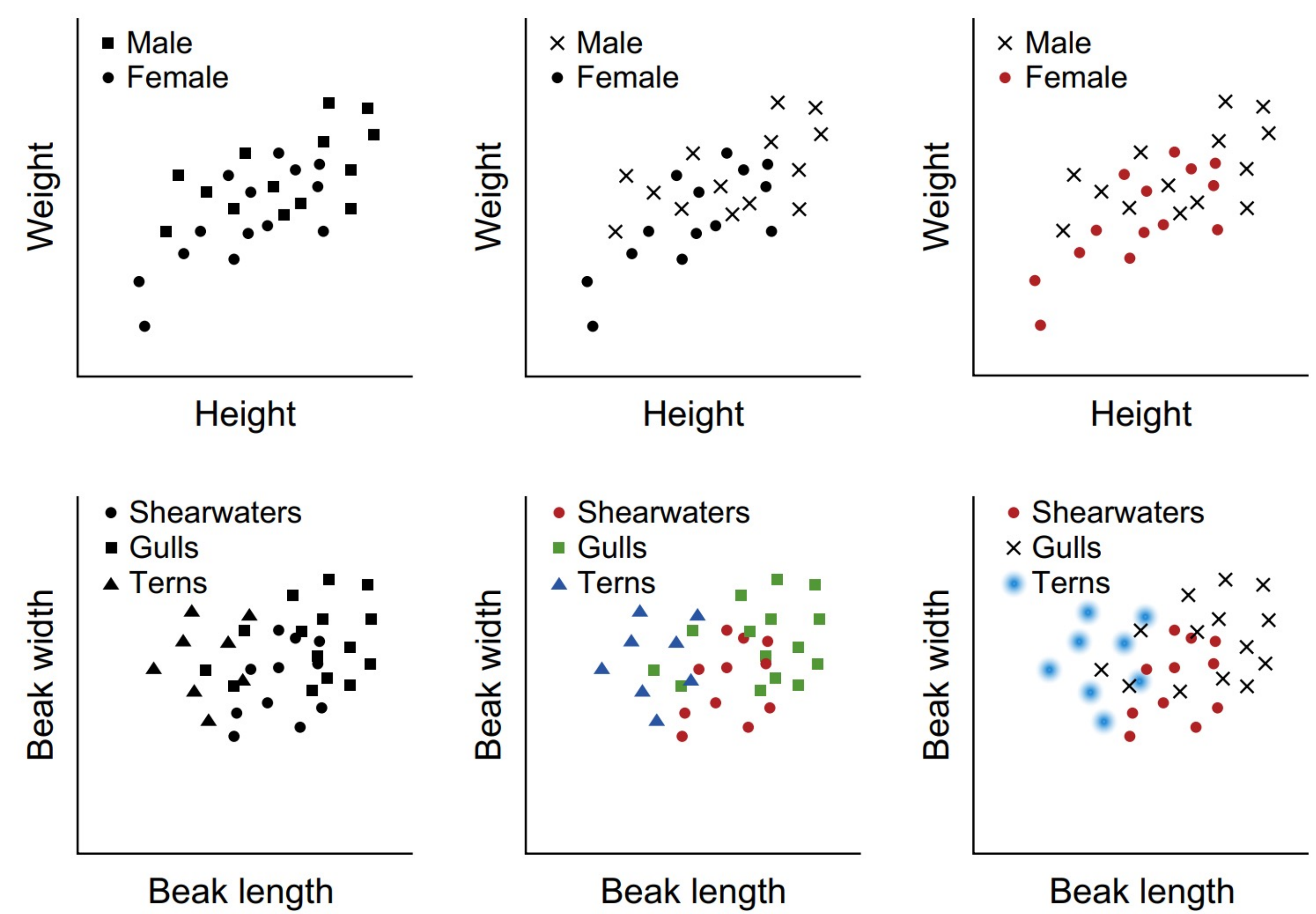


Ware, p. 153, figure 5.6

Glyph

- Ware: “a graphical object designed to represent some entity and convey one or numerical attributes of that entity”
- For maximum visibility, separate different glyphs from each other and from background
  - Frequency
  - Orientation
  - Color

Distinguishing Glyphs

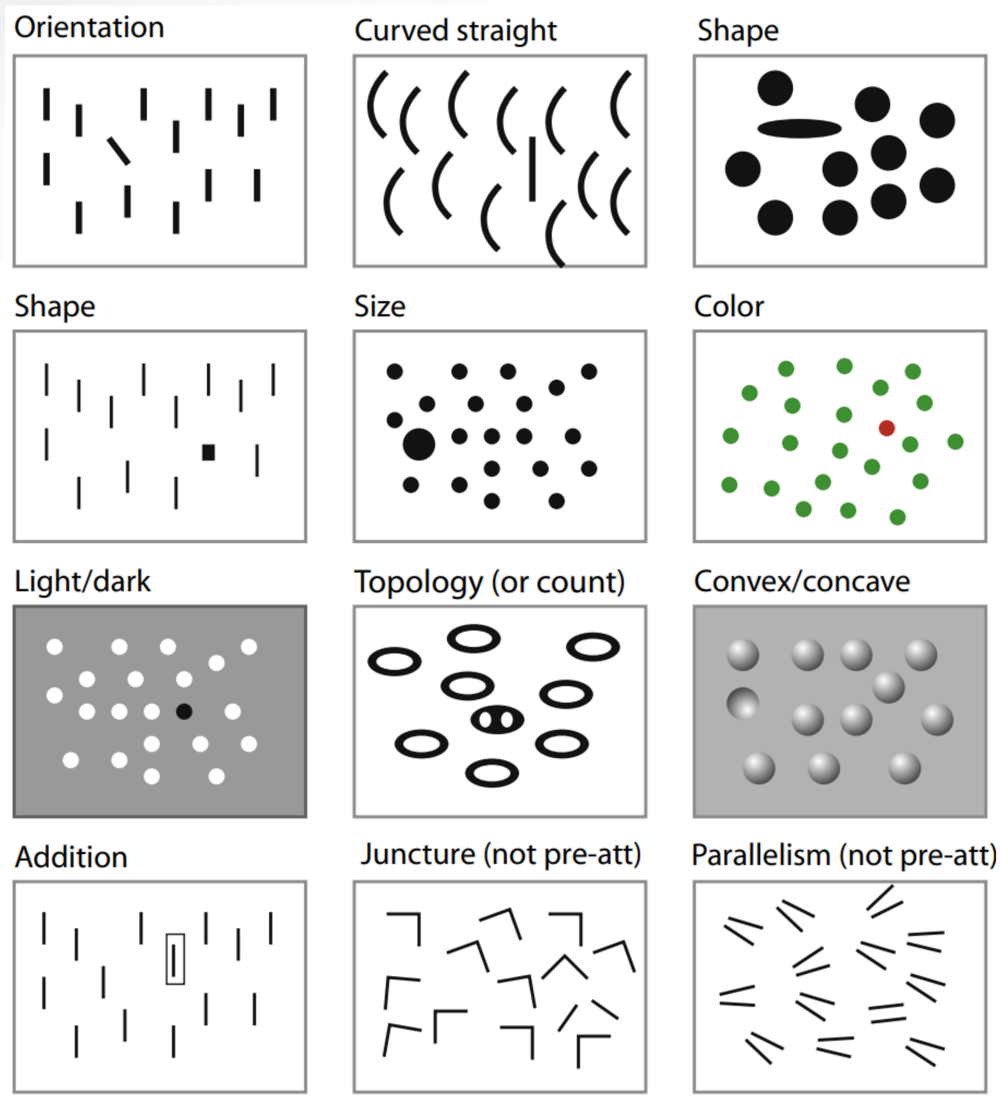


Ware, p. 155, figure 5.9

Preattention

- Visual system processes certain signals at an earlier stage
  - Prior to concentration/cognition
  - Called **preattentive**
- Using these factors allows recognition of unique glyphs faster/easier
  - Picking out glyphs that meet a particular criterion vs. others (distractors)
- Stronger preattentive signals
  - Color, orientation, size, contrast, motion/blink

Preattentive (and not) signals



Ware, p. 158, figure 5.12

Asymmetry

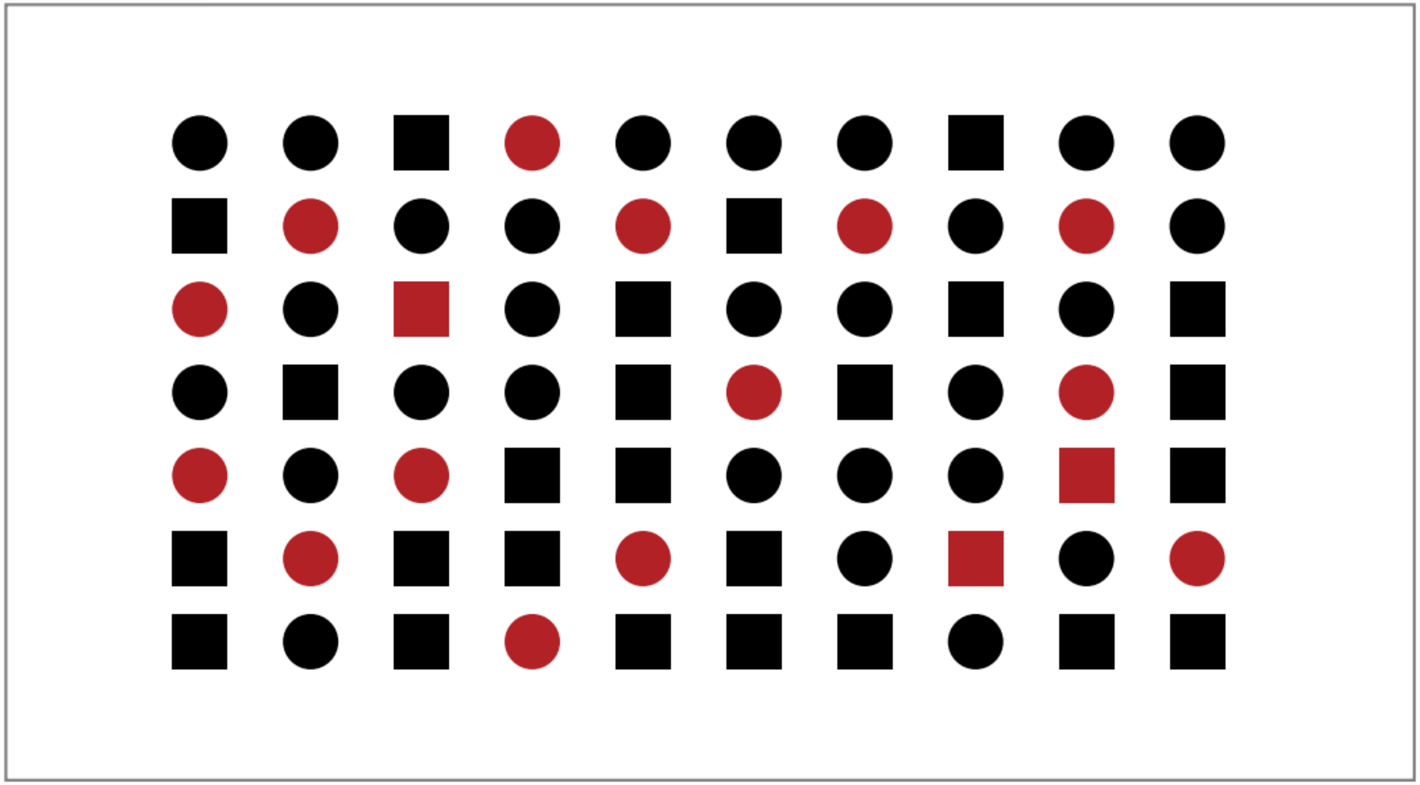
- Even preattentive cues can vary in effectiveness based on other factors
  - e.g. color based on saturation
- Several factors are more effective if used to identify the points of interest
  - Adding features better than removing (e.g. underline key word rather than underline all but the key word)
  - Such asymmetry can be used for highlighting
- To highlight, use channel least used elsewhere in the visualization

Combining Signals

- **Redundant** coding (using more than one channel for same effect) makes things stand out more
  - e.g. use both shape and color
- Should not try to combine preattentive signals (conjunction search); it is hard to separate these
  - There are some exceptions, though

Combining Signals

- Finding red squares is harder than just red or just squares



Ware, p. 162, figure 5.15

Good Preattentive Conjunctions

- Spatial grouping with others including color
- Stereoscopic depth and color or movement
- Luminance polarity and shape
- Convexity and color
- Motion (with most others)

Separable and Integral Dimensions

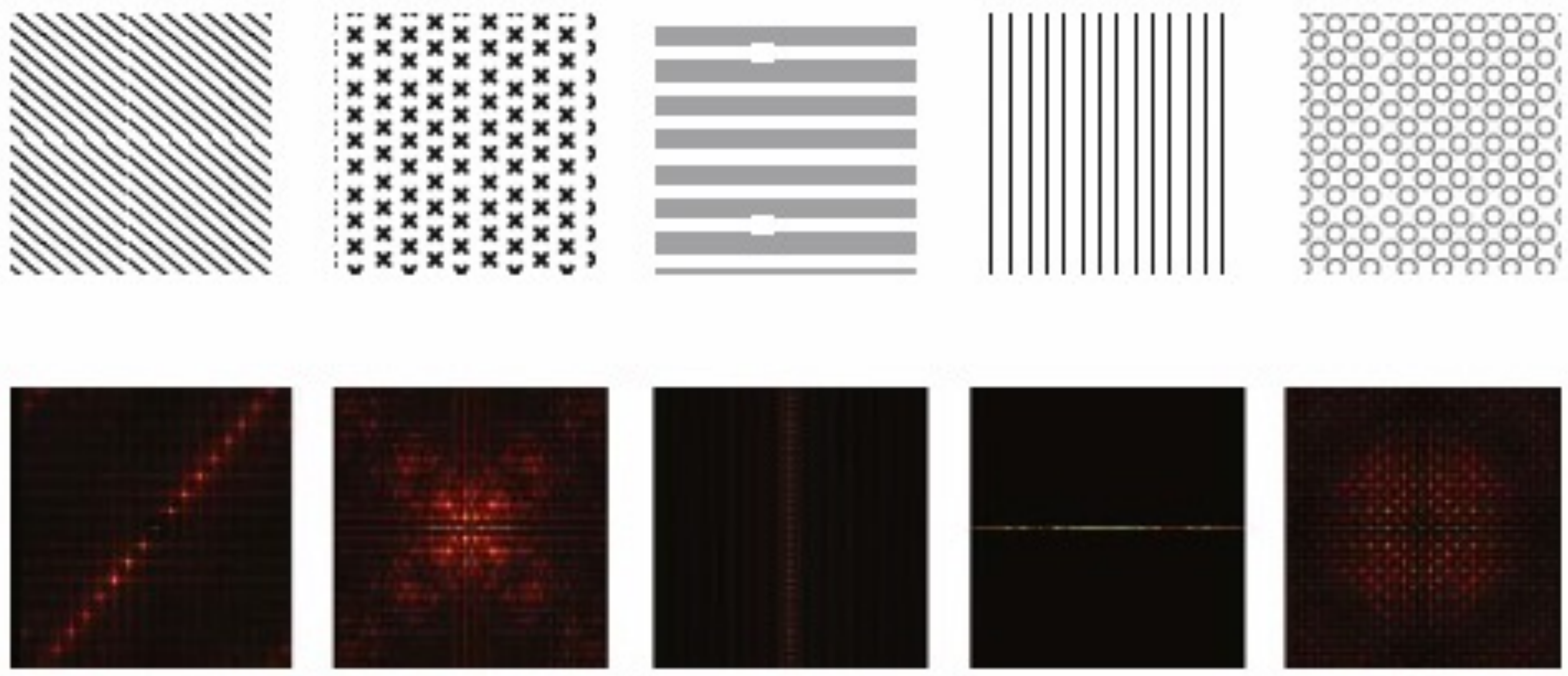
- Channels that are separable are perceived as different; can encode two variables more easily
  - e.g. shape, color, and size
- Integral factors target the same channel and are difficult to distinguish
  - e.g. width and height both perceived just as shape
  - Not good to use these to code more information

Texture

- Texture is used to define regions of space
- Perceptually, we can segment space based on textures
- Textures can vary, but there are 3 main ways they can be characterized
  - Orientation
  - Scale (spatial frequency)
  - Contrast
- Best to vary textures in all three ways
- It's possible to distinguish 12-24 different textures

Texture Variation

- Textures should vary in spatial frequency and orientation



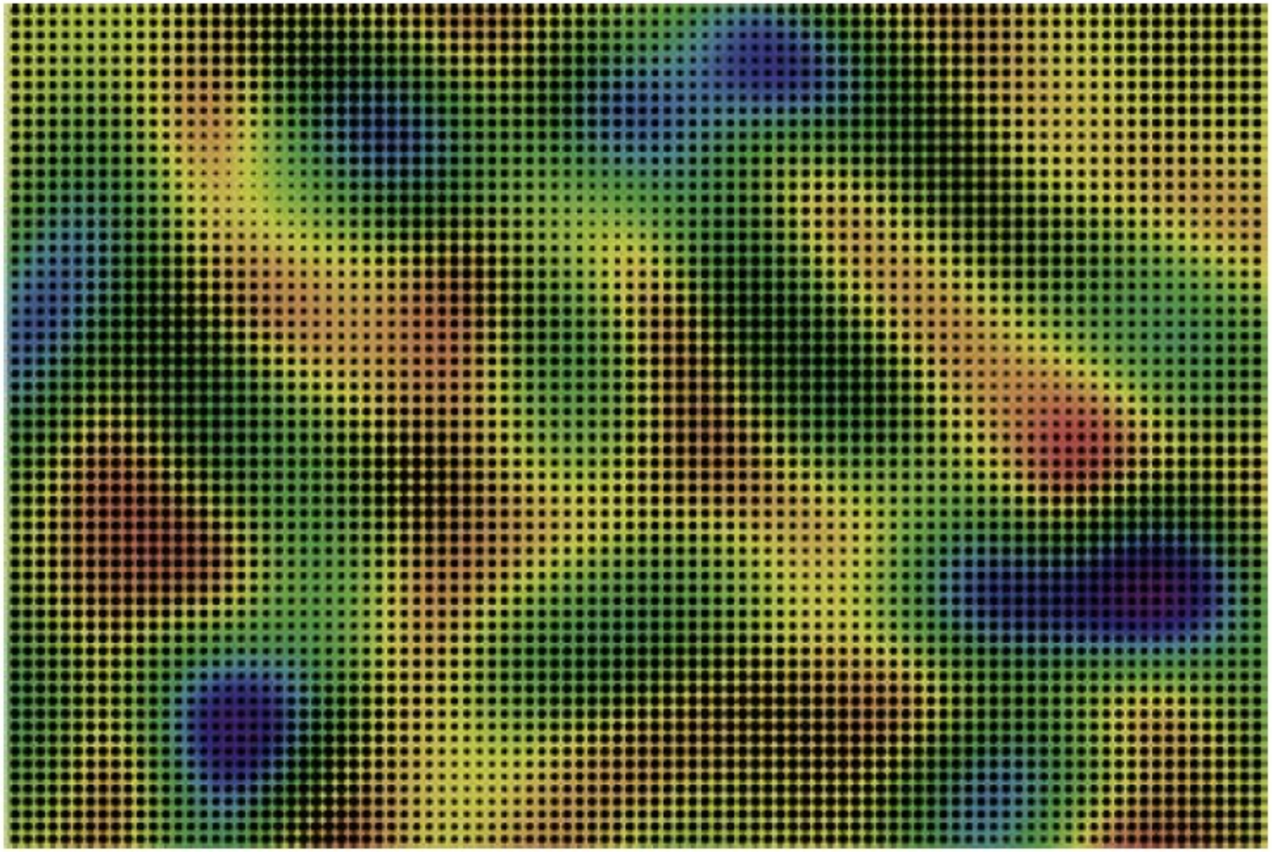
Ware, p. 210, figure 6.39

Texture Use

- Typically in a map environment, but occasionally on a more abstract 2D plane
- Textures can sometimes overlap
  - To show all areas where the texture applies
  - "Laciness" of texture: how well it can be seen through
- Textures have been used to encode continuous numerical data
  - Can vary element size, spacing, or orientation based on some data value
  - If ordinal values, don't use for more than 5 values

Using Texture to Encode Variable

- Color is one variable, texture element size is the other



Ware, p. 212, figure 6.41

Use of Texture

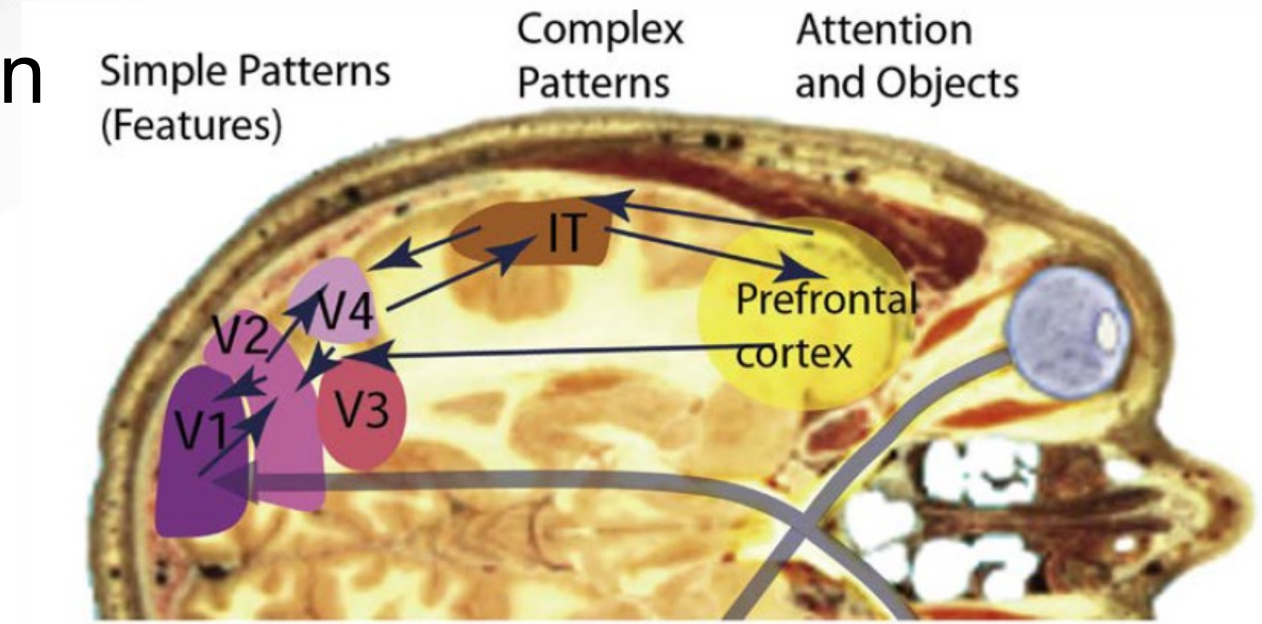
- Some have tried to encode multiple values in texture
  - But, there are severe limitations and tradeoffs, including obscuring other channels
- Textures are limited in perceptual precision (e.g. comparing to a key of values) and placement boundary without contours
  - Need to have clear order of textures, and discrete steps if you want to match numeric values

Final-ish Words on Perception

- Perception is a neural process. Some of this is at a level below conscious attention.
  - It is helpful to understand this, in terms of what is possible to perceive
- Image processing by deep learning: networks tend to converge to similar operations to what has been known for human visual system
  - Lends support to the learned models, and vice-versa

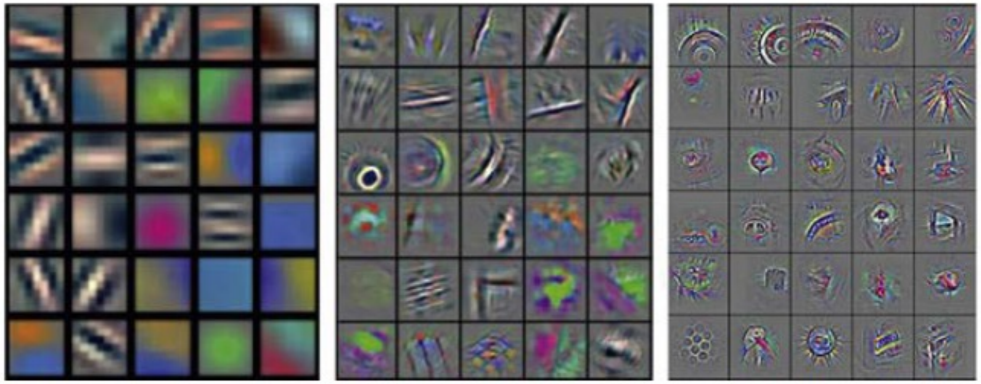
Neural Processing

- In the brain



(a)

- From a deep learning neural net



(b)

Ware, p. 225, figure 6.56