THE BRAIN AND TECHNOLOGY

Brain science in interface design

LESSON 2. CONTEXT

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With illustrations by Jasmin Whitworth

CONTEXT

"When I use a word," Humpty Dumpty said in rather a scornful tone,
"it means just what I choose it to mean – neither more nor less."

"The question is," said Alice, "whether you can make words mean so many different things."

"The question is," said Humpty Dumpty, "which is to be master – that's all." (Through the Looking Glass, Chapter 6)

Context is what **contains** current processing

PART 1: THE PARALLEL ADVANTAGE

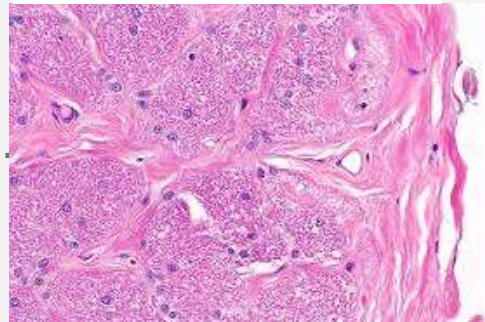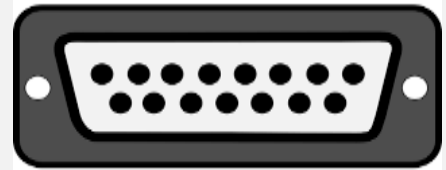**Ali Baba** is in one of forty jars; how best to find him?

- **Sequential***:* A fast slave checks jar 1 then jar 2.
- **Parallel**: 40 slow slaves check each jar.

The computer:

- Has a "parallel" port that has only 25 lines at once.
- Is **sequentially fast** but **minimally parallel**.

The brain:

- Has an optic nerve that has over a million lines at once.
- Is **sequentially slow** but **massively parallel**.

SLOW NEURONS - FAST RESPONSES

- **Computers** are very fast at processing instructions **in sequence**—i.e., one at a time.

  - Computer events take about a billionth of a second.

- **Brains** are much slower but process many instructions at once: i.e., are **massively parallel**.

  - A neuron takes about a thousandth of a second to fire: i.e., is **much slower**.

- **People recognize faces** in about 1/10th of a second.

  - A brain processing sequentially would have to do face recognition in 100 lines of code!!

Dendrites

Cell body

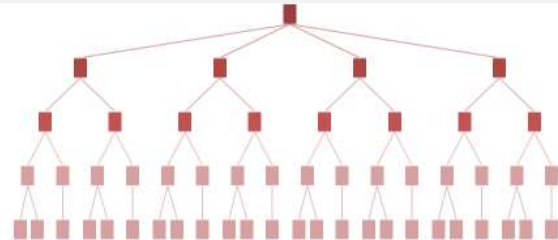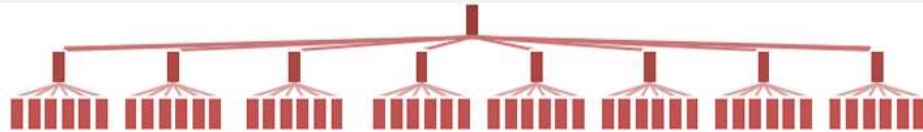Axon - **actually much longer**

Projection
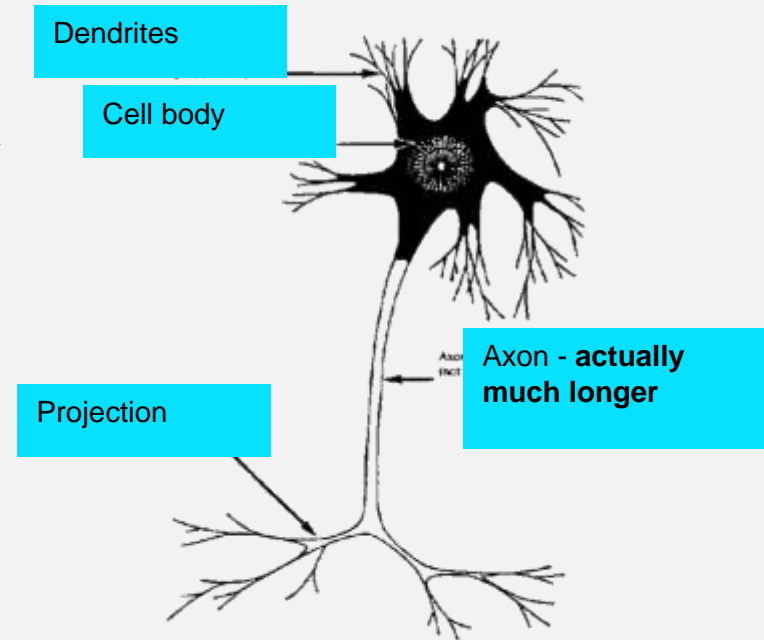
BROAD VS. DEEP PROCESSING

A processing structure can be:

- **Broad**: Wide base with few vertical levels
- **Deep**: Narrow base but with many vertical levels
- **Trade-off**: More input processed less or less input processed more

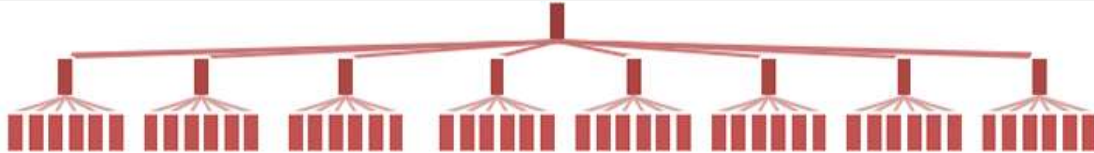**Specialization** allows broad and deep:

- The LH does deep, e.g., language.
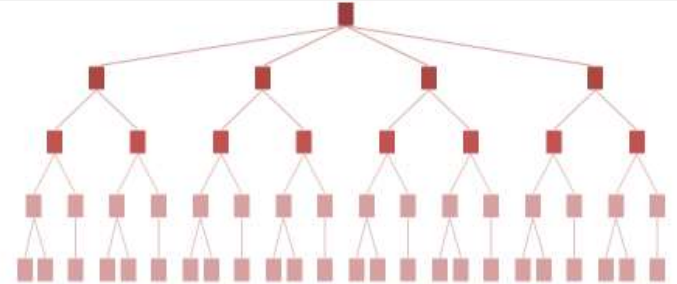- The RH does broad, e.g., spatial.

BROAD AND DEEP PROCESSING

Vision does both:

- **Peripheral vision** processes the entire visual field at a low level.
- **Foveal vision** processes 2-3% of the visual field in detail.

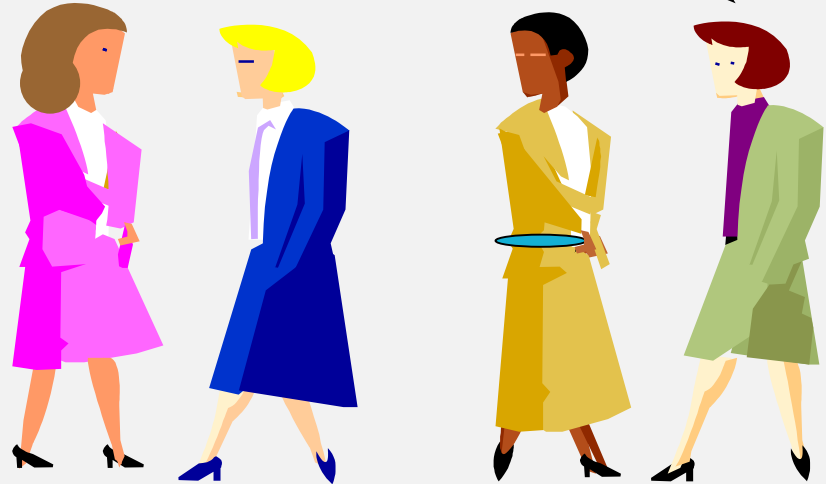Broad processing

Deep processing

PERIPHERAL SENSES

The cocktail party phenomenon:

We **hear** things from conversations we are not (apparently) listening to.

Everything is processed – to some degree.

Do you know **Jane's mother** once said ….

…so they liked what you said, Jane, and decided to follow it up ….

Pre-conscious analyzers can direct attention

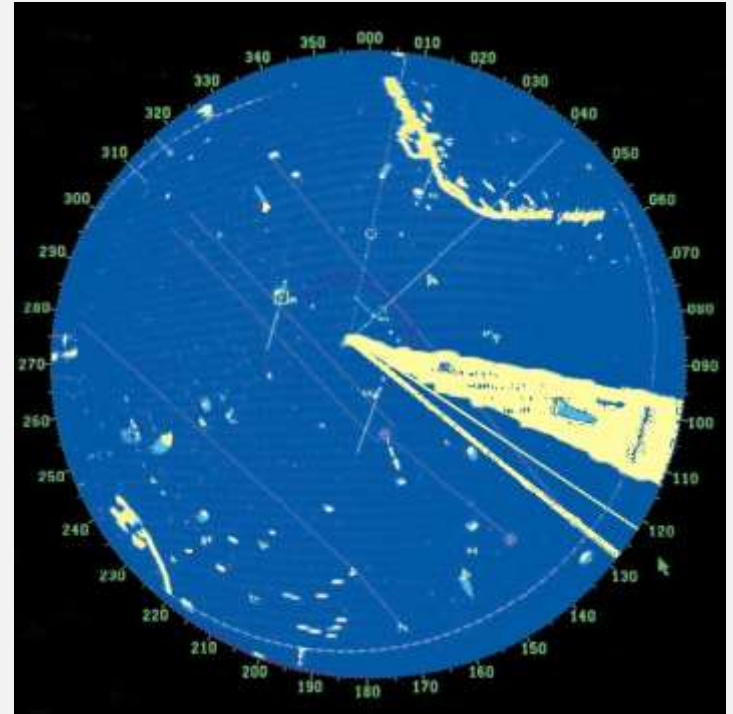# RADAR: WIDE AND DEEP

Radar early-warning systems involve:

- **Detection** of **all** events in a wide area of space and track movement.
  - Simple processing of a wide area.
- **Recognition focus** to identify if it is a friend or foe.
  - Deep processing of a selected target.

Both are necessary:

1. **Broad**: Locate potential targets over a wide area.
2. **Deep**: Identify found targets.

VISUAL EARLY-WARNING SYSTEM

Involves:

- *Detection.* Peripheral vision
  - Analyzes the entire visual field for edges.
- *Recognition.* Foveal vision
  - Recognizes any potential objects.
  - Foveal vision only does 2-3%.

Peripheral vision is all-round awareness of the **entire** visual field.

- Only works if we **listen to it**.
- **Shuts off** if we focus attention, e.g., use a cell phone in a car.
- **Activates** if we look nowhere special, so when driving, look many cars ahead.

Peripheral system for general holistic impression of the situation. Foveal system for high quality details.
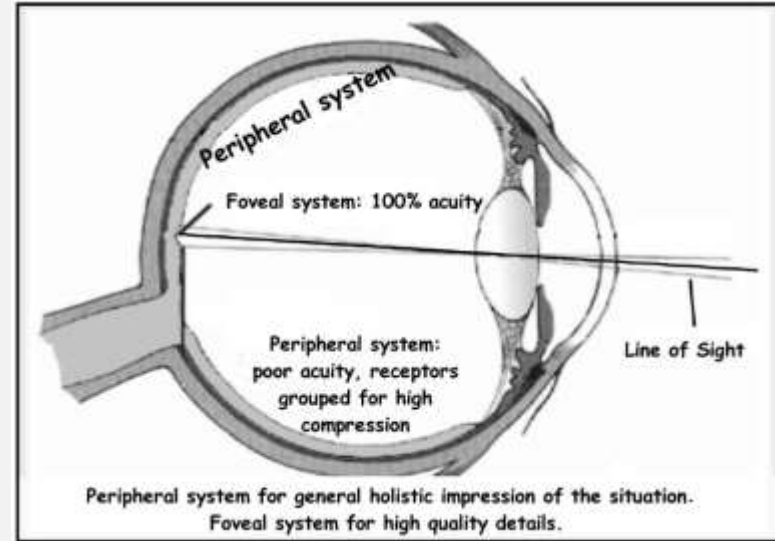
VISUAL STREAMS

Two distinct visual processing streams are:

- **Location***:* **Where** something is - position, distance, orientation and movement (broad)

- **Recognition***:* **What** something is, including color, texture, contour, shape (deep)
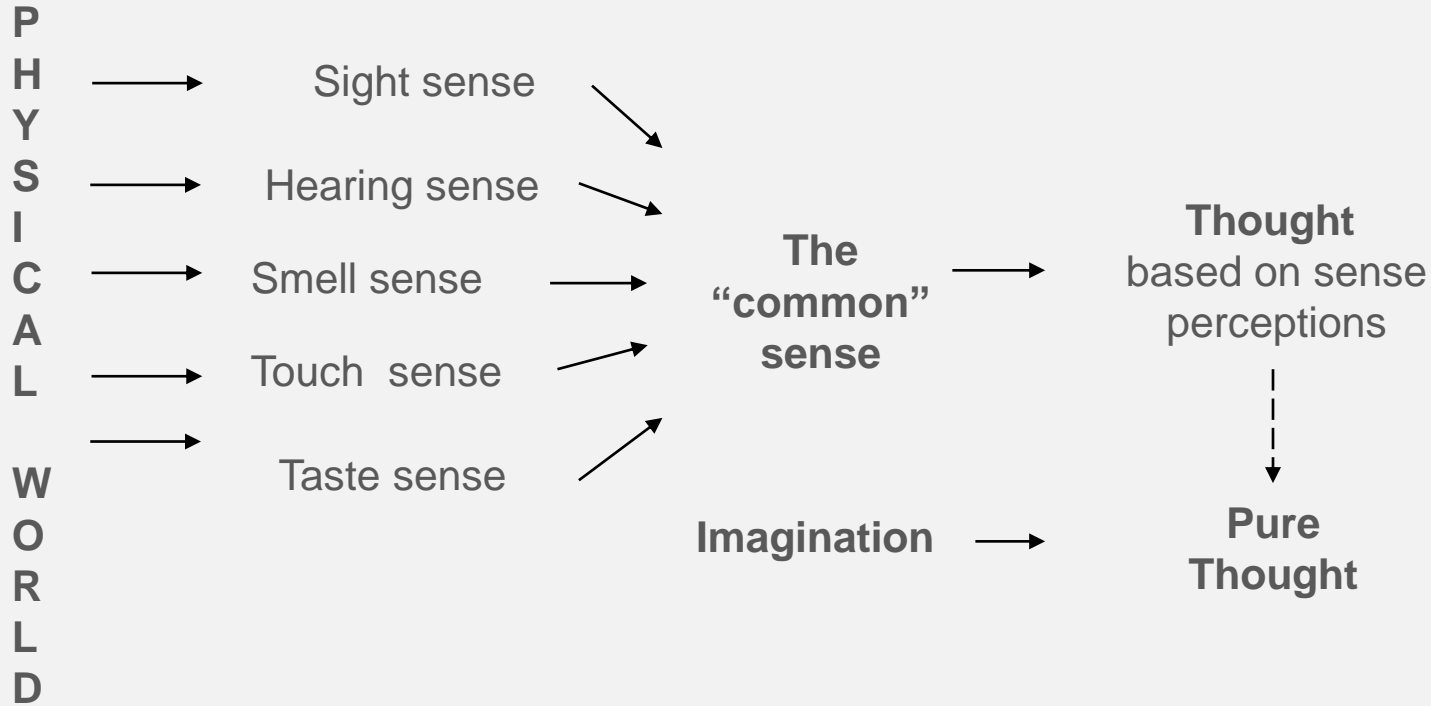
They are **different**, so we can:

- Know something is coming but not what.

- Recognize a thing, but not how close it is, e.g. car headlights at night

Key website cues:

- **Location: Where are things?** Cues include grouping, perspective, shadows and orientation.

- **Recognition: What are they?** Cues include shape, color, texture, size, grouping, distance, key features.

PART 2. THE SENSES

P
H
Y
S   → Sight sense
I
C   → Hearing sense
A   → Smell sense   → The "common" sense   → **Thought** based on sense perceptions
L   → Touch sense
W   → Taste sense
O
R   **Imagination** →   **Pure Thought**
L
D

The brain has more than 5 senses, and information flows down as well as up.

SEVEN SENSES?

Each sense channel has its own analysis hierarchy.

1. Vision: Screen
2. Hearing: Speakers
3. Touch: Mouse, keyboard
   - Feel: Joystick
   - Pressure: Control glove
   - Temperature: Real **hot** keys?
   - Pain: Shock feedback
4. Smell: Scratch-n-sniff screen?
5. Taste: Screen licks?
6. Vestibular (balance): Chair tilt
7. Kinesthetic (movement): Vibra-chairs—movie seats that move

REALISM

Aristotle's realism: We see the world <u>as it is</u>

- Perception is **defined** by sense input (determinism).

- We perceive the physical world because we **reflect** what is outside.

- Outside is **duplicated** in our brains.
  - To people in the Middle Ages, the eye had to make white to see white.

The brain **reflects physical reality** as a mirror does by somehow copying it.

WE REFLECT THE WORLD?

CONSTRUCTIVISM

Plato's idealism held that we **construct** the world out there by interacting with it:

- Perception is not defined by sense input but by **ideal forms** the mind recognizes in reality.

- Brain **constructs** the world we see by processing.

- Each person sees **A** world, not **THE** world.

- Hence we can see **hallucinations** and have dreams that are not based on physical senses.

- Hence we can recognize **abstract** things such as love and three-ness that don't physically exist.

- Hence we can **imagine** what doesn't exist, e.g., unicorns.

- Each person **constructs** his/her own reality.

From Raphael's **The School of Athens** (1509-1511), depicting Plato (left) and Aristotle (right)

Each person constructs his or her own reality.

AND SCIENCE SAYS

Psychology:

- We **construct** language; we don't deduce it (Chomsky).

- We reduce reality.

  - See less than 1% of the electromagnetic spectrum

- **Perception**: the Brain's **best guess** of what is "out there".

Neuropsychology:

- Redness depends on our retinal receptors.

Philosophy*:

- **Kant**: We see **phenomena**, not the **noumena** (the world as it is).

We see   **Bees see**

No part of the electromagnetic spectrum is objectively red.

SIGNAL

Signal: Any **physical** change, representing an **information value,** that can be distinguished from background noise

- **Noise**: changes not caused by the signal
  - **There is never no** background noise.
- **Signal**: a value **distinct from** background noise
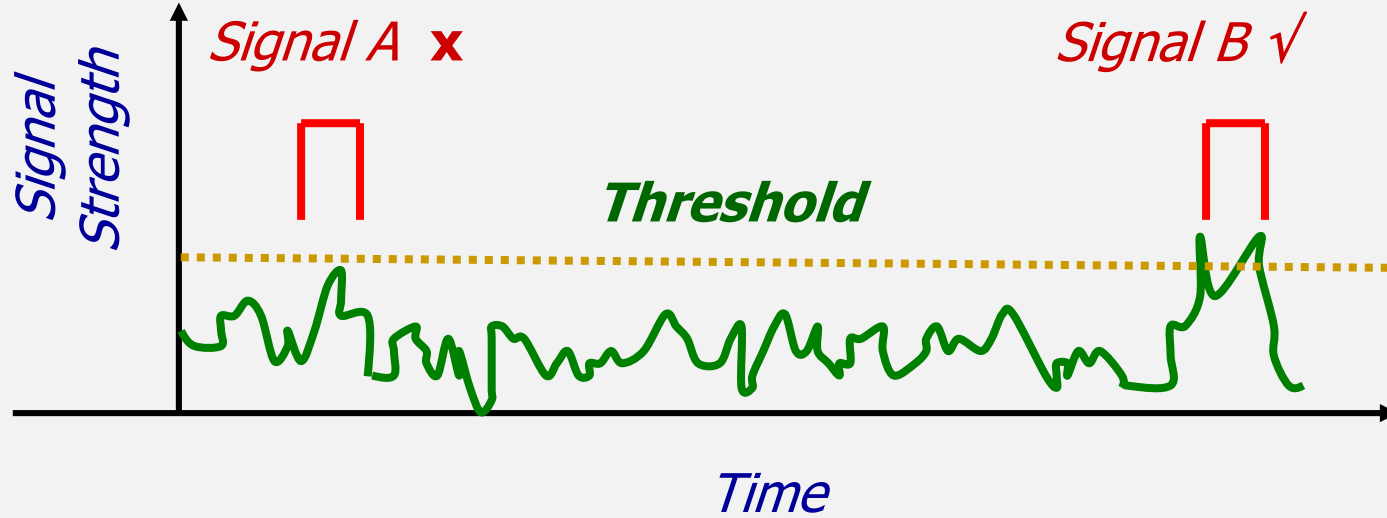- **Threshold**: the level at which a signal separates from the background noise

To improve a signal:

- Increase signal **strength**.
- Reduce **background** noise (irrelevant change).
  - **Filter** out noise.
- Reduce **competing** signals.

There is always background noise

THRESHOLD

- **Threshold** is the signal value necessary to be recognized as not being the background noise.
- A signal must be above the threshold to be perceived.

IS ANYTHING THERE?

Vision: A candle at 30 miles

- The theoretical limit of a quantum of light!

Hearing: A watch ticking at 20 ft.

- The theoretical limit of random motion of air molecules!

Taste: A teaspoon of sugar in 2 gallons of water.

Smell: A drop of perfume in a 6-room apartment.

Touch: A fly's wing falling on a cheek from 1 cm.

Eagles see further, bats hear better, dogs sense fainter smells…
Robins navigate by sensing the earth's magnetic field inclination!

People perceive what
eyes and ears cannot!

THE VOLUME EFFECT

Young children

- Everyone talks at once, so they must yell to be heard – a stressful background.

Adults

- Speak in turn, so they can talk normally.

Sharing attention vs. **competing** for it

- **Signal volume needed** depends on **noise**.

Information environment*:*

- Noisy environments hurt every signal.

- Not **sustainable**

- **The background should not** compete with the signal

A noisy background competes.

PART 3. ENCODING

Information: Depends on the number of signal value options:
- Two choices = 1 bit
- 256 choices = 1 byte, etc.

Encoding: How the signal links to the information
- **Binary encoding**: On or Off signal is 1 **bit**.
- **ASCII** : An eight-bit code for one-byte **letters**
- **Language**: a form of higher encoding

By **different encoding**, the same **on** signal can be:
- One or zero (a bit).
- The first letter, 'A' (a byte).
- The first word, **aardvark** (many bytes).
- The first book - the Zend-Avesta?

More choices more information

The same signal can carry varying information!
- **Hieroglyphics**: carry no information if we can't decode them!
- **Data compression** stores more information in the same physical signal by better encoding!

Information is encoded!

ENCODING SCHEME

Better encoding: Same information **for less bits**

- A picture can be encoded as a:
    - Bitmap (BMP) – pixel based.
    - Compressed bitmap (GIF).
    - Line-based image (JPEG).
    - PNG (Portable Network Graphics format).
        - JPEG is better for CAD work.
        - Bitmaps are better for non-linear graphics.
        - **Vector** formats (e.g., pdf) store squares more efficiently than **raster** formats, such as gif, do.
        - Pick an **encoding scheme** for your purpose
- **All the languages of the world are just encoding schemes**.
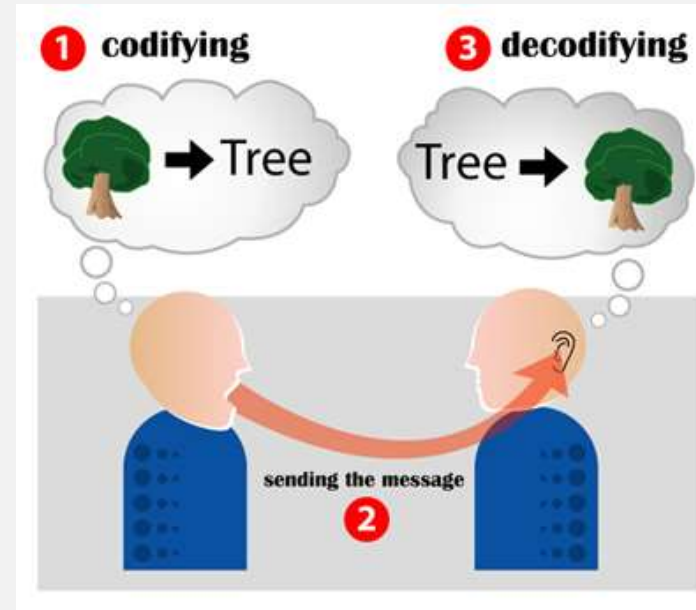
GRAPHICAL ENCODING

Symbols*: Graphics whose meanings are understood in every nation*

DECODING

Decoding: Turning a signal back into meaning

Decoding time increases with **the number of options**.

- 7 is one of **ten** numbers.
- F is one of **26** letters.

Longer time to recognize

- A word is among **millions**.

People recognize numbers faster than they do letters.

- "50% Off "is easier to read than "Half Price" or "Two for One"

Questions: Having fewer options means less decoding and a faster response.

- **Default:** Indicate the likely choice option.
  - **Helps**: If based on **my** usual choices
  - **Hinders**: If based on what **you** (the business) wants?
- **Bad premade choices make for more cognitive work**: e.g., *Install McAffee*

Many options is more brain work.
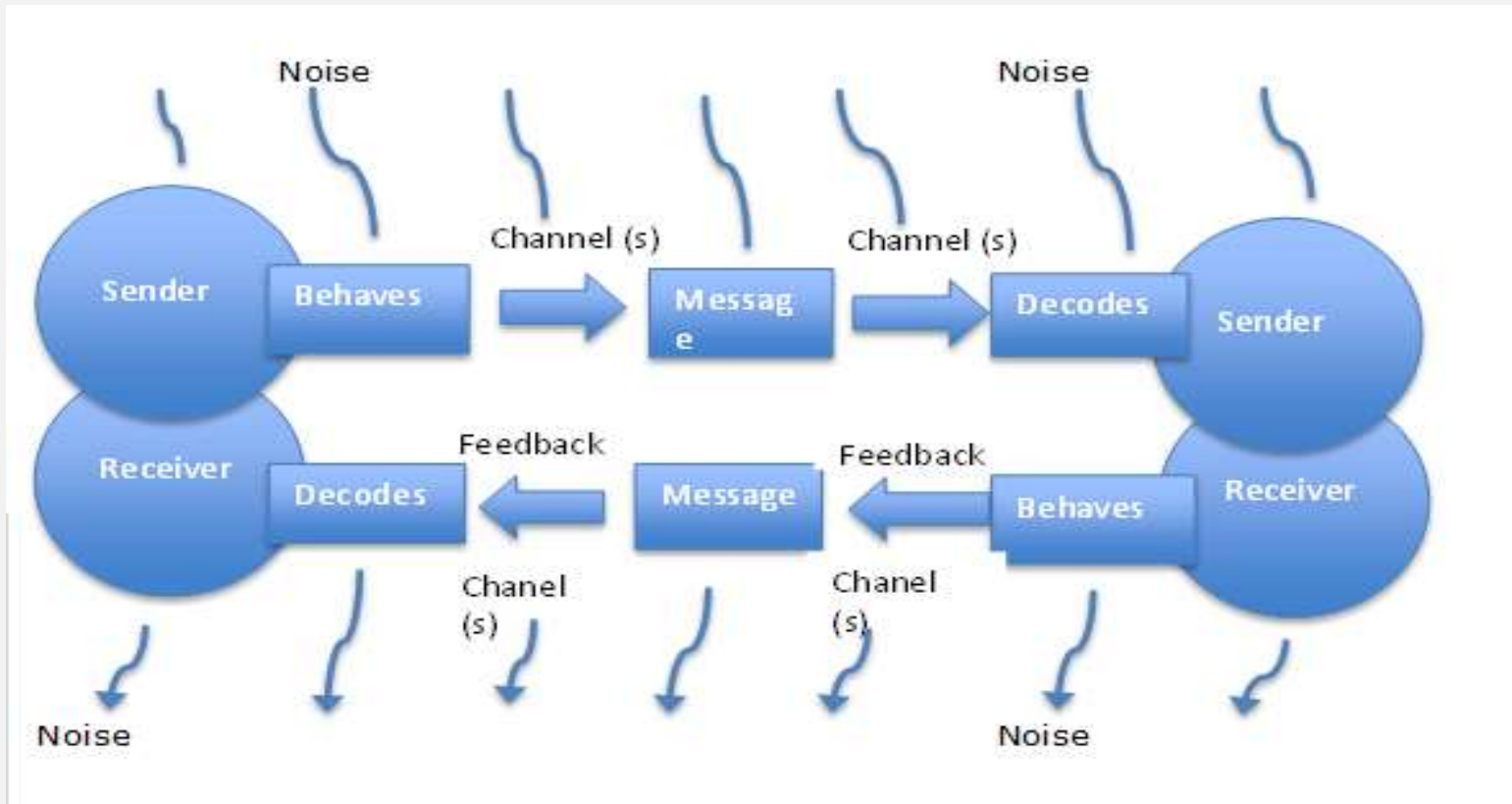
Information is exchanged by encoding and decoding.

THE THIRD OPTION

Computers reduce choices to **binary** bits, but there are always at least **three** choices in any **life** situation.

- Left, right or **stay - do nothing** is a choice!
- Agree, disagree or ignore
- **Victor Frankl** on life in a Nazi concentration camp:
  - Submit and help the guards.
  - Fight and be killed.
  - Transcend and refuse the pain.
  - **His conclusion**: There is always a choice.

The two main choices are obvious; the third is contextual.

- **Vote:** Yes, No and
  - **Don't know:** No knowledge on this issue
  - **Abstain:** On record as not voting on this
  - **Refuse to vote:** Wrong question or wrong options

Victor Frankl

Look for the third option, in design and use.

WHO CONTROLS THE CHOICES?

The choices control the outcome.

- Power to define the **question.**
  - When did you first start hating Stalin?
- Power to define the **options.**
  - Power **reduces life** to binary choices.
  - Hitler: Us vs. them, cf. EU political unification
  - ISIL: Islam vs. the West, cf. religious unification
- Power to <u>deny</u> **third choices.**
  - Abstain, Don't Know, Discuss, The right to silence

Software: The new power tool?

- Every question needs a close window option.
  - For software that doesn't, use Task Manager.
- Good software gives **three** choices:
  - Allow cookies, Deny cookies, **Let me choose.**
    - Mozilla just dropped the option **to be easier? Smartphones just allow all cookies.**

Help improve this article

💡 Suggestion　　😊 Praise　　😠 Problem　　😕 Question

Make a suggestion! How can this article be improved?

By posting, you agree to transparency under these terms.

**Post your feedback**

TERMINOLOGY (1)

- **Information**
  - Base 2: Log of the number of physical options
  - A choice from on/off is one bit.
  - No choice is zero bits.
  - 1 Byte is eight bits.
- **Processing** – Changing an information value
- **Channel** – An information stream
- **Bandwidth** – Channel's information capacity
- **Instruction** – Tells a processor what to do
- **Control** – How the next instruction is decided
- **Encoding** – Turn information into a physical signal
- **Decoding** – Turn a signal into information

00110101
1 BYTE

TERMINOLOGY (2)

- **Information overload***:* Too much information to process it all fully
- **Boredom***:* Not enough information to occupy the brain
- **Sensory channel**: Vision, hearing, smell…
- **Analyzer***:* Neural assembly that processes selected input to generate an output
- **Output***:* Can affect muscles, organs, hormones or, more often, other analyzers
- **Habituation***:* Reduced response to a signal that constantly repeats
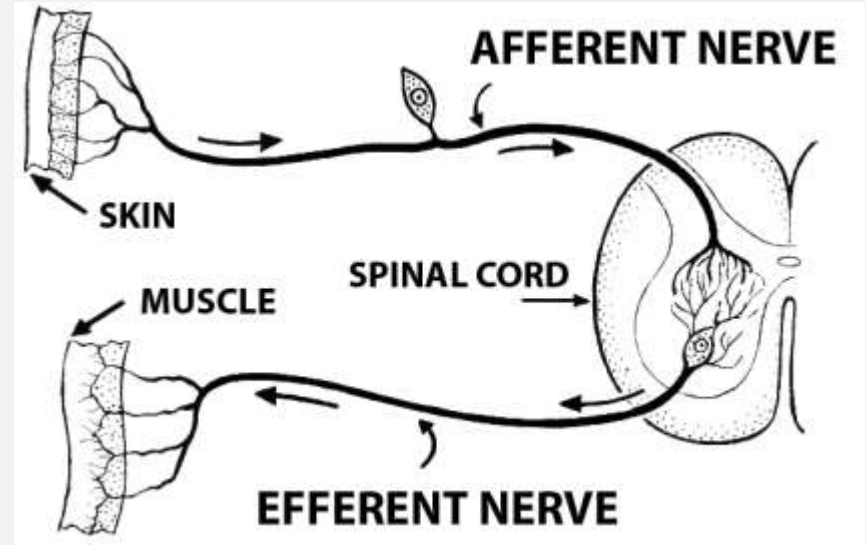
The simplest case

TERMINOLOGY (3)

- **Attention**: How the brain manages processing control
  - **Expectancy** - Downward attention control
  - **Distraction** - Upward attention control

- **Consciousness**: The brain **observer (Buddhism)**
  - Information **sink**: Where information goes
  - Information **source**: Where choice comes from

- **Meaning**: Information plus consciousness
  - The brain converts **information** to **meaning**
  - **Semantic web** occurs when people interpret data.

PART 4. BORDERS

In sunlight

- 1-5 million cones mainly in the fovea give **color vision**.

In dim light, they don't work

- So, **100 million rods** take over.

- Black/white was the first visual process.

- We are initially blind in sudden darkness because daylight bleached the rods.

- The rods make a light-sensitive chemical after about twenty minutes to give night vision.

The eye camera has **two types of film:**

- **Cones**: For daylight vision

- **Rods**: For night vision

Rods and cones are types of photosensitive cells in the retina.

THE FIRST STEP IN VISION

- The retina is actually a part of the brain – the brain grows out to form it

- In its visual processing—

  - One type of retinal cell (1) responds to light increases **above background level**

  - Another type of retinal cell (2) responds to light increases **below background level**.

BOUNDARY AMPLIFICATION

- Retinal cells interact laterally to amplify each other.

- The result is **boundary or edge** amplification.

- An edge is where light turns to dark.

Boundaries underlie all object recognition.

Retina

Magnification

Neural activity

Minimization
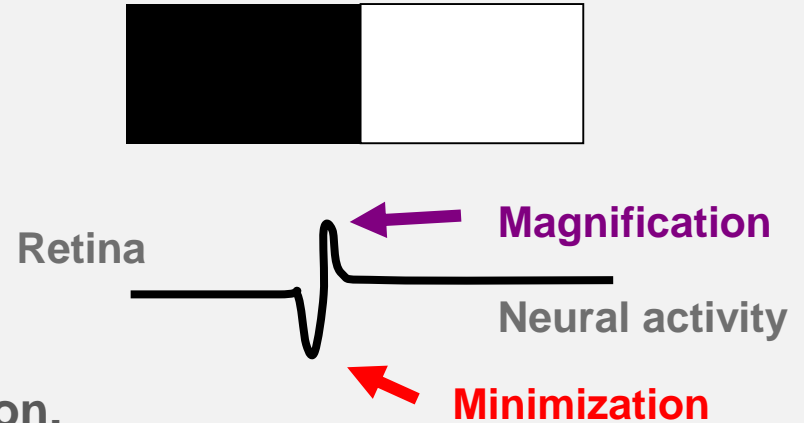
BLURRING TEXT

- Blurring text by shadow or embossing reduces readability.
- If you **must** do it, **compensate** by:
  - A larger font
  - Fewer words
  - Shorter words
  - Sans-serif fonts
  - Enhanced color contrast
  - Enhanced boundaries
- Blurring **backgrounds** is good!

Hard **to read!**

Harder to read

Still hard to read

More contrast helps

Font Arial, not TNR, larger,
three, not five words,
black contrast

VISUAL BASICS

The first step of visual processing that occurs at the retinal level is to identify border contrasts.

- **Borders** are critical to all higher visual processing—e.g., shape recognition.

They easily convey important information.

- **Progress bars**: How much done
- **Scroll bars**: There is more below

Border changes always draw attention:

- Outline objects needing action
- Frame important pictures
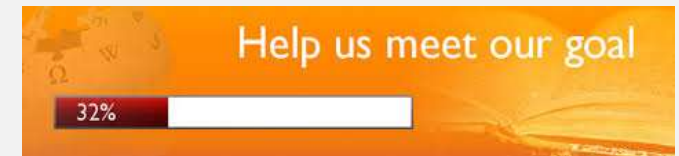
ENHANCE BOUNDARIES

Boundary enhancement always helps.

- Especially for small or unfamiliar figures

Best practice

- Thicken shape contour outlines.

- Increase all border contrasts.

- Use color, texture or saturation to increase contrast.

Boundaries are the basis of all shapes.

Boundaries stand out

OTHER ANALYZERS

- Each square mm of the visual cortex contains about a quarter of a million cells.

- It has **simple, complex, and hyper-complex** layers.

- Different cells do different analyses.
   - E.g., some cells only respond to certain angles.

Stimulus:

Cell 1 response

Cell 2 response

10º changes
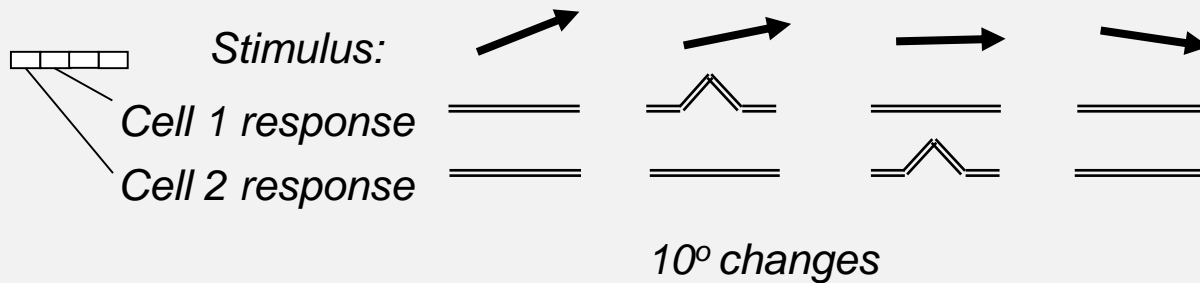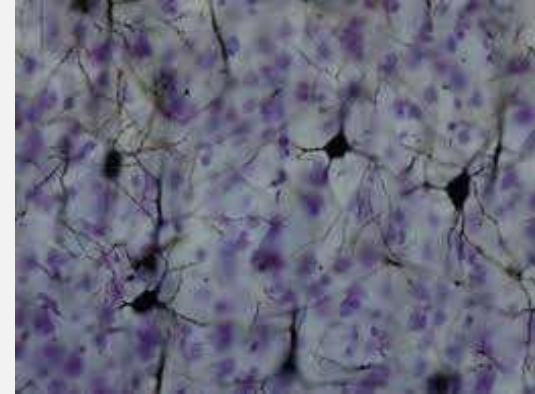
PART 5. CONTEXT

- **Context:** The assumed background—e.g.:
  - **Visual context**: Background graphic
  - **Information context**: Encoding scheme
  - **Thought context**: Mathematical **axioms and assumptions**
- Lower processing is *contextual* to higher processing, and the brain is processing upon processing
  - E.g., figure ground assumptions
    - Is there anything in yours?
- But higher processing **airbrushes** the result.
  - Lower processing is affected by higher **biases**.

(its mail box!)

The wall context is assumed.

CONTEXT IS A CHOICE

Pretty blue bird

Nasty Swamp grass
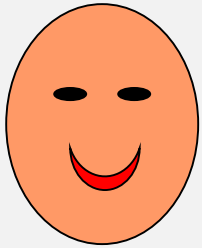
Focus of attention?
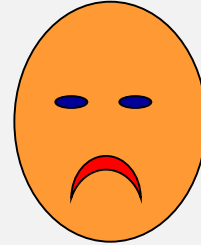
What we ignore depends on what we attend.

THE CONTEXT ADVANTAGE

Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a total mses and you can sitll raed it wouthit a porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe!

There actually was no such research, but the example shows how

- **Word shape**, a context, helps word meaning.
- We scan the first and last letters (**anchoring**).

Information overload **requires the brain** to use **context** (prior processing)
to guide **attention** (current processing)

Without a common encoding scheme, no meaning is exchanged.

THE CONTEXT DISADVANTAGE

Impossible figures occur when context **assumptions** fail or contradict.

- Two square prongs or three round?
- Impossible fence posts!
- Walking up forever?
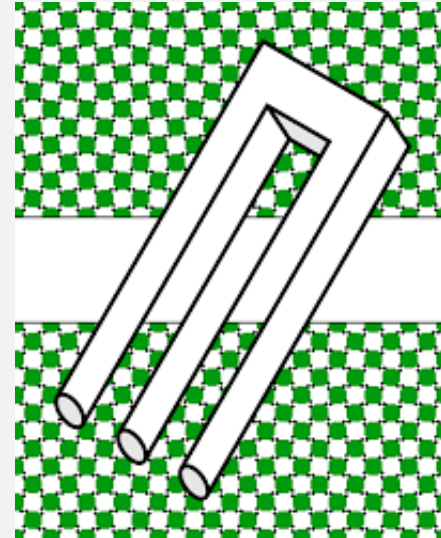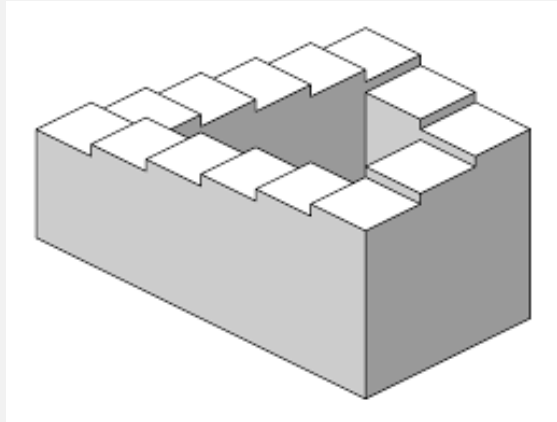
BOTTOM-UP PROCESSING

Upward control: Visual cortex processes **upward**, as lower analyzers pass data to higher ones

- **Simple→ complex→ hyper-complex cells**
- So, lower effects can accumulate errors.
    - Is that a square you see?

But there are also:

- **Lateral effects**: Same-level analyzers enhance or inhibit each other.
    - E.g., to enhance borders
- **Downward effects**: **More** nerves project from the visual cortex to the lateral geniculate than vice versa!
- **This system alters its own input!**
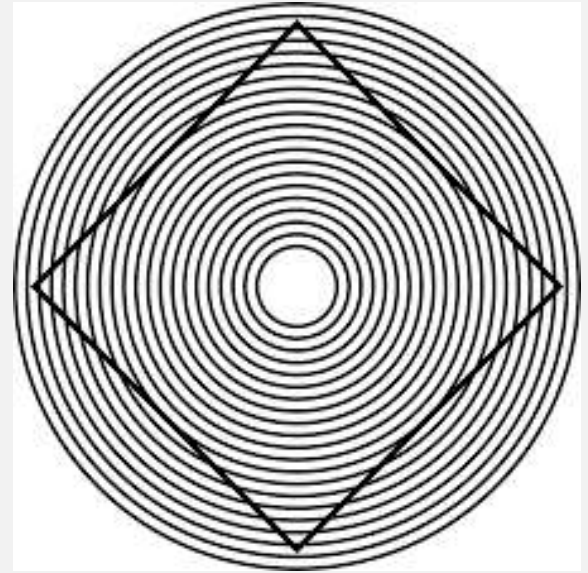
Yes it is square!

TOP-DOWN PROCESSING

James Gibson's 1966 theory proposed that perception involved mainly **bottom-up processing**.

Richard Gregory in 1970 argued that perception is a constructive process based on **top-down processing**.

- See the discussion at http://www.simplypsychology.org/perception-theories.html

Perception is a **top-bottom negotiation** between:

- **Naivety**: Seeing what is, however silly
  - The Emperor's New Clothes: Only the child saw it.
  - Honest children are socially naïve.
- **Bias**: Seeing what is expected or **should** be there
  - Doing what people above expect is social **corruption**.
  - **Whistleblowers** reveal corruption.

BIAS IS PRIMING

Bias is when a prior processing **context** predisposes a certain **perception**—e.g., bearded men are bigger.

Words create sentences, right?

- Computers that process one way (input to output) analyze letters to words to sentences.

The brain works both up and down so:

- **Word analysis** suggests sentences.
- The **likely sentence** then alters the words to fit!
  - The sentence also creates the words!

Bias is a problem for science, but **priming** the brain based on **context** is necessary to handle life:

- **Hit me** in blackjack
- **Hit me** in boxing

Read this sign:

Now read it again

PART 6. ENVIRONMENTS

Environments contain and sustain entities (people and things).

- **Physical**: Time, space, light, air, ocean, weather

- **Informational**: Linux, Windows, Java, game worlds, Internet, WWW

- **Social**: Nations, communities, work places

Environments are generally ignored - Fish don't see the water; birds don't see the air, and people don't see social environments – **until they fail.**

- **Physical environments**: Pollution of air, rivers and lakes. **Climate change** is the Earth adjusting our physical environment.

- **Information environments**:

  - **Money:** Is just information – a currency can collapse.

  - **Great depression:** A whole economic environment failed.

- **Social environments** can also "collapse" by crime and corruption.

  - **Toxic work environments**: Harass and bully workers.

  - **A toxic Internet**: Would be full of lies, hate and deceit

West of Delhi

VISUAL ENVIRONMENTS

Recall that visual processing depends on:

- **Signal power** (frequency, strength…)

- **Noise** (background power)

- **Receptor type** (cone vs. rod)

- **History** (e.g., habituation)

- **Contrast** (borders)

- **Context** (bias or priming)

A visual **background** is the environment that **contains** whatever we are looking at.

It is as **important as the signal** in creating an effect.

British Museum environment

VISUAL ENVIRONMENTS

Perception is signal **and** background, so choose a **background** that **supports the signal**:

- **Dark** foregrounds need **light** backgrounds.

- **Light** foregrounds need **dark** backgrounds.

- **Fuzzy** backgrounds make a signal clearer.

- **Sharp** backgrounds **compete** with the signal.

- Backgrounds can have backgrounds …

People don't usually **click** on backgrounds because they ignore them.

- – Right-clicking on a background to change it works.

- Right-click an empty screen to change its picture.

- Right-clicking on Toolbar changes its properties.

Which game do you like?

SOCIAL ENVIRONMENTS

We are now **building social environments online**

- Facebook, E-Bay and Wikipedia are **socio-technical environments** based on hardware and software.

They work the same as **socio-physical** environments.

- **People migrate** out of negative environments:
  - The EU refugee migration is an example.
  - It's much easier to "migrate" online.
- The online social culture caused the **Arab spring**.
- **Socio-technical gap**
  - Between what the technology does and what people want
  - Technology needs to recognize **social requirements**, like fairness, transparency, trust, privacy and freedom.

Leaving an environment hurts

NEGATIVE & POSITIVE ENVIRONMENTS

Negative social environments are:

- **Negatively driven***:* Mistakes are punished, success ignored.

- **Corrupt***:* Who you know, not what you know.

- **Bureaucratic***:* Focused on rules rather than results.

- **Chaotic***:* Cheats, thieves, liars and bullies thrive.

- **Secretive**: No-one knows what is going on.

- **Image focused***:* Focus on appearances not performance.

Positive online social environments are:

- **Positively driven**: Reward good acts so creative people stay.

- **Impartial**: Treat inhabitants equally.

- **Free**: Allow individuals choices—e.g., open source.

- **Fair**: You reap as you sow.

- **Transparent**: People see the governance—e.g., Wikipedia.

- **Production focus**: Generate new things—product orientated.

PERSONAL CONTEXTS

Every **message** has a **sender** context:

- Who sent this is the message context.

Every **act** has a **purpose** context.

If you **set a cookie**:

- **Who** are you? (do I trust you?)
- **Why** are you setting this cookie?
- **What** are the consequences for me?
  - **Trust me; I know what I am doing?**
  - **Lightbeam reveals** cookie links.
  - People won't trust selfish software.
  - An Internet without trust is **socially dead**.

The Wolf and the seven young kids

Lightbeam

TRANSPARENCY

Site/app visitors want to know your contexts:

- **Personal***:* **Who** are you? (give a photo), What is your **past**? (offer a bio)

- **Social**: What **groups** do you belong to? (country, culture, religion)

- **Motivational**: What is your **purpose**? (tell it up front)

- **Financial**: Who is funding this?

Transparency lets people leave or stay faster

- Door sellers who won't say what they are selling!

- Cookies that don't say why: Why does the **American Journal of Psychology** set 23 cookies when I visit?

- Do apps observe secretly, record secretly, and upload secretly?

- Should I cover my laptop camera, or close it in my bedroom?

- Can I trust my smartphone for online banking?

Why all the cookies?

PART 7. DESIGNER NOTES: CONTEXT

Border contrast

- The biggest thing screen designers forget: white space.

Repetitive background

- Wallpapers are good backgrounds because they repeat.

Use depth

- Adding depth gives 3 dimensions, a feeling of space.

Blurring

- Make crowd faces fuzzy, blur text & colors, do motion blur.

Mood

- Use background to set emotional context, e.g., color.

Avoid distraction

- Avoid things such as people, faces, events and text that distract.

Backgrounds of backgrounds

- The same principles apply.
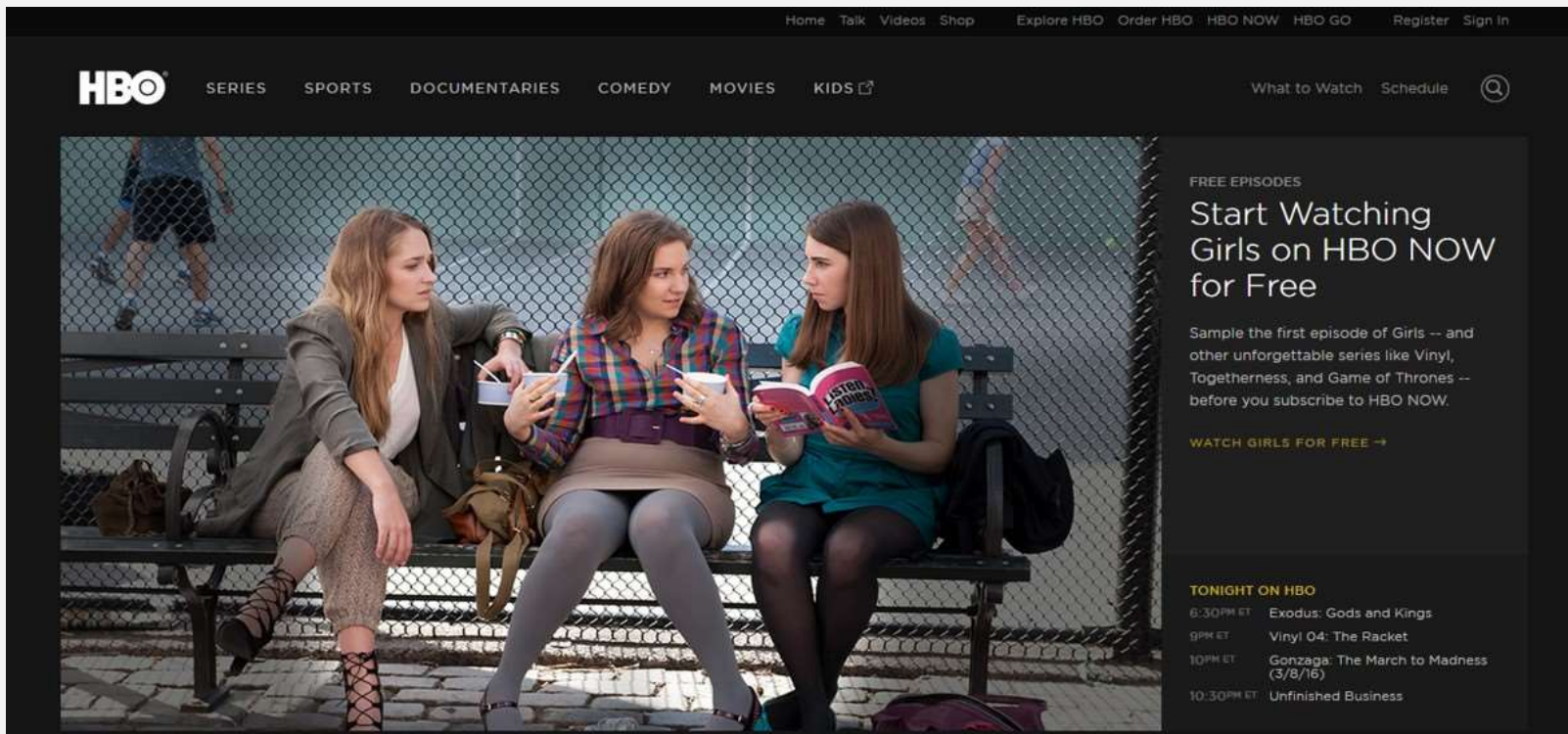
The same rules apply to:

- *Sound backgrounds (Muzak)*
- *Social backgrounds (Culture)*

BORDER CONTRAST

REPETITIVE BACKGROUND

ADD DEPTH

BLURRING

BACKGROUND MOOD

DON'T DISTRACT

BACKGROUNDS TO BACKGROUNDS

William Blake's
Ancient of Days