2. Sensations and Attention

The truth is out there…

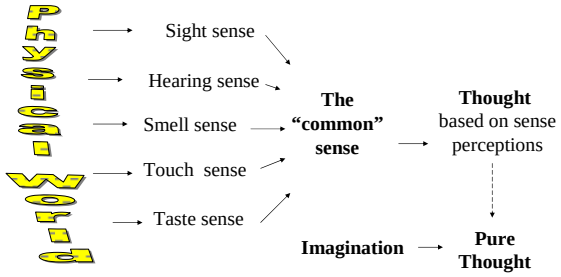
Aim

How does the brain deal with sense data?

How does this affect the design of HCI systems?

Aristotle's view

Link: Aristotle



Note: There are actually more than 5 senses

Sensation is reality

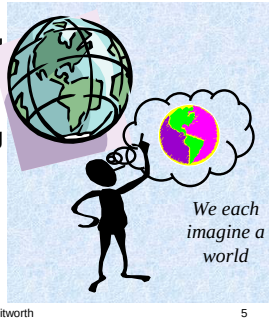
- Perception is a physical change in the body senses
- Aristotle thought external changes create a mirror copy of the real world inside us. (i.e. when we see white, our eyes in some way create whiteness)
- Implies that sensations reflect stimuli

We reflect the real world?

Sensation is imagination

Link: Hallucination

- Aristotle also proposed "pure thought", not derived from the senses
- We can "see" what is not there, like MacBeth seeing a dagger
- We can conceptualize apart from the world (can one see "threeness", or "love"?)



We each imagine a world

What is perception?

- Perception *reflects* reality - it is a small (but faithful) copy of reality
- Perception *reduces* reality – we see less than 1% of the electromagnetic spectrum (EMS)
- Perception *enhances* reality - what we see is as much imagined as real

All these views seem to be correct

Terminology

Link: Coding, Bit

- *Channel* – signal input stream
- *Bandwidth* - channel capacity
- *Information* – no. of possible values a signal can have
- *Analyzer* – neuron assembly processing a given way
- *Encoding level* – degree signals are processed by the brain - higher encoding carries more information:
  - **1 pixel/dot** ---------- low level encoding (bitmap)
  - **1 shape** (e.g. a square) -----higher level encoding (vector)

The seven senses

- Vision
- Hearing
- Touch (touch, pressure, temperature, pain)
- Smell
- Taste
- Vestibular sense (balance)
- Kinesthetic sense (body movement & position)

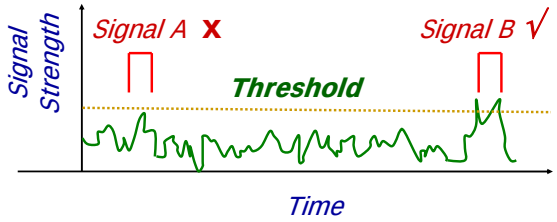
All sense channels operate simultaneously, each with its own low level analyzers

What is a stimulus?

- A stimulus is not just a signal, but *a signal apart from* background signals, or "noise"
- The world is always changing at every level, including random molecular/atomic changes, there is never "nothing" or no change
- The physical level at which a signal is noticed is the *signal threshold*

Signal threshold

Physical energy above the threshold is necessary for perception



Link: Detection

Is anything out there?

- *Vision* - candle flame at 30 miles - the theoretical limit of 1 quantum of light!
- *Hearing* - watch ticking at 20 ft - the theoretical limit of random motion of air molecules!
- *Taste* - 1 teaspoon sugar in 2 gal. Water
- *Smell* - one drop perfume diffused in 6-room apartment
- *Touch* **-** fly wing falling on cheek from 1cm

The limit of senses is the random noise of the environment

Link: Isolation experiments

Boredom

- Brain is designed to detect signals. If there are none, it creates them!
  - sensory deprivation subjects, exposed to white noise in floating chambers, have hallucinations
- Beings with complex processors become "bored" when those systems have nothing to do
- *Application:* To activate and engage human processing is the first requirement of web site design – i.e. *avoid boredom - change things*

Link: Psychophysics

Physical stimulus vs. sensation

- *Luminance* (L) - the amount of light, as measured by a light meter
- *Brightness* (B) - the amount of light perceived
- What is the relation between L and B, where B is the "*just noticeable difference*" (JND) (usually about 1-2%)

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Link: Just noticeable differences

Just noticeable difference (JND)

- JND *increases in proportion to signal strength*
- *Weber's law*: B = Log_{10}(L) i.e. x10 increase in luminance gives 1 perceived brightness increase
  - *i.e.need a greater change at higher amplitudes to notice it*
- *Stevens extension*: B = Log L to base *x* – where *x* varies with senses
- Our senses flexibly adjust their sensitivity – like they have a "volume control".
- So turning up the volume doesn't equally turn up the effect!

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Link: Hearing

Why JND is not fixed

- Senses cover a *vast* stimulus range:
  - Hear from 0 - 100 decibels - a ten thousand million fold increase in air pressure
  - Light range from bright sunlight to moonless night is likewise very great
- Equal sensitivity is neither possible nor necessary at all signal magnitudes

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Link: Psychophysics

Perception is relative

- There are no sensory "units" - our numerical quantitative judgements are astonishingly poor (e.g. judging speed, or "half as loud")
- Good at detecting *differences* over a *wide stimulus range* (e.g. which light is brighter?")
- *Human perception is relative not absolute*
- *Application*: People prefer more or less decision to absolute numbers (e.g. Bigger/Smaller? vs font size?

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Application: Role of background

- Signal detection depends on **both signal and background**
  - Strong colors need a light background
  - A quiet background (e.g. white) lets less signal (e.g. smaller fonts) have the same effect
  - Use white "space" to get effects
- Choose web site background to contrast the main "signal" sent

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Neural frequency and signal strength

Link: Adrian

- A nerve either fires or it doesn't (i.e. is a *binary* response mechanism)
- How can a binary mechanism reflect continuous changes in signal strength?
- For stronger signals *the nerve fires more often* i.e. firing frequency reflects signal strength
- More frequent is more likely to activate other neurons

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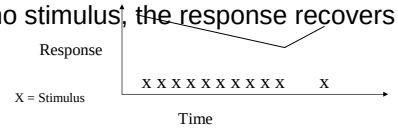
Habituation

Link: Habituation

- *Given a steady input signal*, nerve firing frequency decays with time, e.g.
  - Where a single nerve connects sense receptor and muscle (spinal reflex), with *repeated* stimulation the reflex decays over time (some do not)
- With no stimulus, the response recovers



Sensory adaptation

Link: Habituation

- Habituation: the brain protects itself from too much information by "tuning out" unchanging stimuli, e.g.
  - Upon entering a room a new smell is noticed. With time (repeated stimulus) it seems to disappear, e.g. we don't notice our own smell (or the smell of our group)
  - A man in a new house awoke at 2am shouting "What was that?" as a train rushed past. Eventually he slept through it. One night the train broke down - at 2am he awoke shouting "What was that?"

Adaptation application

- What works depends on past stimulation
  - Flashing banner ads are now ineffective as people have adapted to ignore anything that looks like a banner advertisement
  - Pop-up windows, which normally catch attention, are now closed before even being read
- What works changes as people adapt - web sites must also adapt

The sensory dilemma

Link: Attention

- A newborn baby faces:
  - Many input signal channels (senses)
  - Operating over vast amplitude ranges
  - With complex spatial and temporal patterns
  - Where small changes can have big effects
- Immense amounts of complex information, changing continuously, coming in too fast to process =

INFORMATION OVERLOAD!

A baby sees a 'blooming, buzzing confusion" (William James)

Information overload

- If *more information* comes in than can be *processed*
  - It is not new! It is the primary problem of the senses
  - We adapt by "tuning out" the irrelevant and focusing on the relevant - ***usually what changes***
- Two solutions:
  - **Select the information** to **process** (by attention)
  - **Improve information processing** (by higher perceptual processes)

Solutions to information overload

- *Short term adaptations (often don't work)*
  - Ignore stuff (wear blinkers like a horse)
  - Process faster (panic like in a fire)
  - Run away (leave the field, e.g. don't use email, Facebook, etc)
- *Long term adaptations*
  - Pick out what is important (attention)
  - Use a higher level of encoding (see the forest not just the trees)

Application: Information overload

- Avoid screen information overload if possible
- If not
  - Help the user's attention process - draw attention to what they first need to know, e.g. by color
  - Make higher analysis processes easier - use layout design to give a meaning structure, e.g. boxes round similar menu options

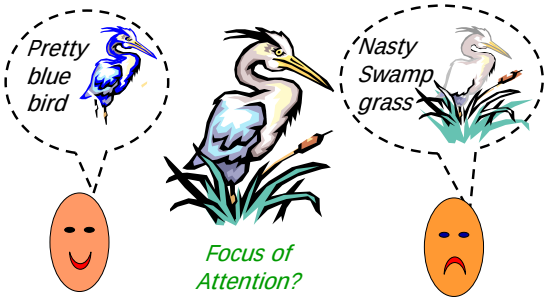
Attention

Link: Attention

- How incoming information is *selected* for analysis *when it cannot all be processed*
- *Application:* If you present a lot of information on a screen, **most** of it will be ignored
- The *focus* of attention selects 2-5% of input to actually process fully – the rest is *assumed*

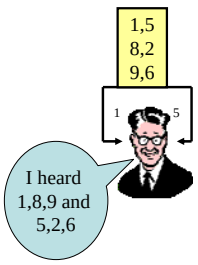
(e.g. we hear one sound among many, we see one part of the visual field, we feel one area of skin etc)

Focus of attention affects meaning



Broadbent's Filter Model

- Two sets of numbers (signal streams) presented to two ears (channels) *at the same time*
- The stream attended to first *appears to the person to have occurred earlier*



Conclusion - one analyzer

- Broadbent's Filter Model:
  - Signals from each ear go into a local short term memory
  - A *single* "analyzer" switches between the two cache areas
  - So signals appear consecutive in time
- *Application:* If people process words by a single analyzer, the *sequence of meaning* is the *order of attending*
- For one analyzer processing multiple channels, *the sequence of attention must be managed*

Link: Attention

The Stroop Task

BEAR
LYNX
EAGLE
GOAT
HORSE
WOLF
RABBIT
FOX

Try to remember the animals on the list, and their colors

The Stroop Task

BEAR
LYNX
EAGLE
GOAT
HORSE
WOLF
RABBIT
FOX

What where the animals on the list?

What color was the HORSE? The WOLF?

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The Stroop Task

GREEN
ORANGE
BLUE
ORANGE
RED
GRAY
YELLOW
PURPLE

Try to remember the colors named in the list, and also their colors

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The Stroop Task

GREEN
ORANGE
BLUE
ORANGE
RED
GRAY
YELLOW
PURPLE

What where the colors on the list?

What color was the RED? The GRAY?

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Conclusion: > 1 analyzer

- One signal is processed by two analyzers - one for meaning and one for color
- If analyzer outputs for one signal conflict there is interference (between word meaning and ink color), i.e. mixed messages
- *Application:* Differently processed aspects of the same signal should support not conflict, e.g.
  - *Color and layout should match the site theme, e.g. a business site needs business colors and layout*

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Multi-processing

- If
  - input channels are separate (separate senses)
  - and responses are automatic (learned)
  - and they do not compete (use the same output)
  - Two channels can be processed at once without interference e.g. we can talk and drive
- But if two analyzers process and respond to the same source, they *interfere* or *support*
- So design web sites so *vision* and *text* complement, e.g. *using both graphic and text on button controls as Netscape did succeeded (cf Microsoft's buttons)*

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Link: Reaction time

Expectation -Top-down control

- *Preparing* ("priming") analyzers to process a certain way improves performance
  - *Reaction time* for "expected" signals can reduce, even to 0 seconds!
- *Higher* analyzer *predictions* can direct *lower* analyzers (hence "top-down" attention control)
  - Without prediction cricketers could not catch or bat!
- False expectation = ***bias***, a major accident cause!
- *Application*: Manage user expectations!

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Application - consistency

- Analyzers operate more efficiently if prepared, either by repetition or priming
- Too many changes of font, style, size, color and layout slow down brain processing, as analyzers must re-adjust and refocus for each change
- *Be consistent and frugal with fonts and colors*
- *Be predictable in layout and effects*

Link: Attention

Distraction - bottom up control

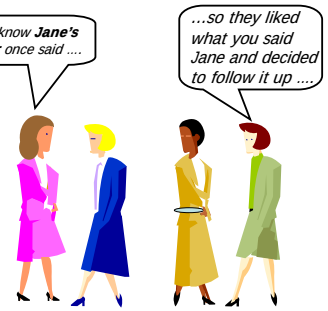
- While subjects attended to one channel (ear), a distracting message was presented to the other
- Certain words "got through" the filter, and were heard!
  - Emotional words (e.g. our own name)
  - Contextually probable words
- *How can we hear our name in the second channel if we were not processing it?*
  - a sleeping person who hears their own name,
  - a sleeping mother who hears her baby cry

Link: Cocktail party effect

The Cocktail Party Phenomenon

We "hear" things from other conversations that we are not (apparently) processing

Pre-conscious analyzers operate continuously and can direct attention



Link: Brain function and awareness

Pre-attentive analyzers

- *Blindsight* - subjects with visual cortex damage, *verbally* report no vision in an area, but can still *physically* respond to some visual stimulus accurately, e.g. to catch a ball thrown
- *Amnesia* - subjects with no conscious memory of a jigsaw puzzle solve it faster with repetition
- Attention can be directed by any level of analyzer
  - *Not all knowledge is conscious verbal knowledge*
  - Base analyzers have the autonomy to direct attention automatically (i.e. without being directed)

Ironic processes

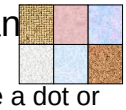
- *Ironic Processes*
  - To decide to ignore something you need to know what it is. In knowing this, you have failed to ignore it.
  - E.g. For the next 10 seconds, do not think about a *white polar bear*
- To resolve these paradoxes the brain uses shared rather than centralized control
- *Application*: Avoid things that distract people from the main point(s) of your site

Link: Vision, the early warning system

The early warning system

- Two processes (cf radar system)
  - **Detection** of significant event in a large space (bottom up attention control)
  - **Focus** (zoom) on selected target for continuous tracking and detailed analysis (top down focus)
- Both processes are necessary
  - Detection is broad but simple
  - Focus is complex but narrow

Detection - texture chan



- Repetition of a simple signal (like a dot or mark) gives a texture
- Such repetition is the basis of *backgrounds or fill* (e.g. tiling)
- People "effortlessly" process textures *over the entire visual field (not just focal area)* to see:
  - Texture gradients (continuous changes)
  - Texture boundaries (between textures) -> lines

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LINK: Textons

Textons

- Textons are the repeated detail elements of a texture
- Can only discriminate by *first order properties* - i.e. element properties, not element relationships
- Must be a certain denseness (closeness compared to size)
- Distinct from shape recognition (next lesson), which involves relating and connecting elements in patterns, and requires *focus*

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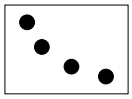
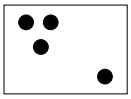
Texton properties - collinearity

- *Collinearity* - ability to form a line or elongated blob
- Texture based on A is strongly discriminated from B, because A forms a line and B doesn't (both have the same number of dots)

A 

B 

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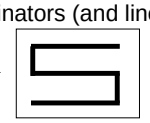
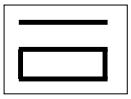
Texton properties - terminators

- Number of line terminators has affects texture discrimination
- Textures A and B are not distinguished (though focally one is an S and one a sideways 10) because they have the same number of terminators (and lines)

A 

B 

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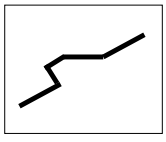
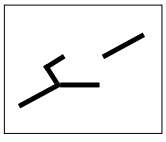
Texton properties - terminators

- By contrast the following textures are strongly discriminated though both have the same lines - one has two terminators and the other five





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Pre-conscious visual processing

- The visual early warning visual system *effortlessly* identifies/discriminates textures across the entire visual field, and directs attention to any texture boundary lines, or areas of discrepancy
  - Uses simple local properties of small repeated elements
  - *Occurs prior to form or figure recognition*
- *Applications*:
  - Adding a background increases fullness of effect at no extra psychological "cost"
  - Backgrounds can also help to *structure* information
  - Controls like progress bars are easy to process

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How to get attention foc

- Place message where focus already is or likely to be (e.g. center of screen)
- Change the signal - the more the better
- Change in more than one modality or aspect
- Present something simple and/or known (e.g. name)
- Present something emotional (e.g. threatening)
  - Police siren - maximum signal changes in two modalities (visual & auditory), both color and brightness change, usually moving fast
  - McDonalds - 1 letter, bright color, rainbow

Summary

- Signal effect depends on *change* from background
- *Habituation* - reduced response to a repeated signal
- *Boredom* - when there are no changes to process
- *Information overload* requires selective attention
- *Expectancy* - downward attention control
- *Distraction* - upward attention control
- *Pre-conscious analyzers* can "automatically" direct attention
- *Visual early warning system* detects texture changes

Application recap

- *Textures* add additional sensory experience at no extra cost (i.e. do not increase information overload)
- *Texture changes* are immediately and effortlessly be drawn to attention e.g. a progress bar
- People **don't** read everything on the screen!
- Be *consistent* and frugal with fonts, colors so analyzer priming will reduce user effort and speed processing
- Avoid things that *distract* attention from main points
- Manage user *expectations* (so they are not disappointed) - be mainly predictable in routine things
- Manage the *sequence* of user attention

Homework – To Read

- Attention- read about vigilance
  - http://en.wikipedia.org/wiki/Attention
- Vision, the early warning system - radar and the two system processes, textons.
  - http://www.sciencemag.org/content/228/4704/1217.full.pdf
  - http://www.medecine.unige.ch/recherche/schnider/documents/pdf6.pdf
- Brain function and awareness: the blind-sight experiments are fascinating studies
  - http://www.answers.com/topic/brain-function-and-awareness
- Code and Bits: understand the basic ideas here - we return to them later
  - http://en.wikipedia.org/wiki/Code
  - http://en.wikipedia.org/wiki/Bit
- Psychophysics - Weber's law etc Don't try to follow it all – just understand that our senses don't work like mechanical sensors
  - http://www.answers.com/topic/psychophysics
- Habituation
  - http://en.wikipedia.org/wiki/Habituation

OTHER LINKS

- Hallucination
  - http://en.wikipedia.org/wiki/Hallucination
- Detection
  - http://www.answers.com/topic/detection
- Isolation-experiments
  - http://www.answers.com/topic/isolation-experiments
- Just Noticeable Difference
  - http://www.answers.com/topic/just-noticeable-difference-1
- Habituation
  - http://www.experiment-resources.com/habituation.html
- Hearing Sense:
  - http://en.wikipedia.org/wiki/Hearing_%28sense%29
- Reaction Time
  - http://www.answers.com/topic/reaction-time
- Cocktail Party Effect
  - http://en.wikipedia.org/wiki/Cocktail_party_effect
- Aristotle
  - http://en.wikipedia.org/wiki/Aristotle
- Adrian
  - http://en.wikipedia.org/wiki/Edgar_Douglas_Adrian

Next: Perception

- What are the base elements of perception?
- Can we trust our perceptions?

Why can you see a triangle that "factually" isn't there?