ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Humans

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Topics

Perception: senses

- Sight
- Hearing
- Other senses
- Movement

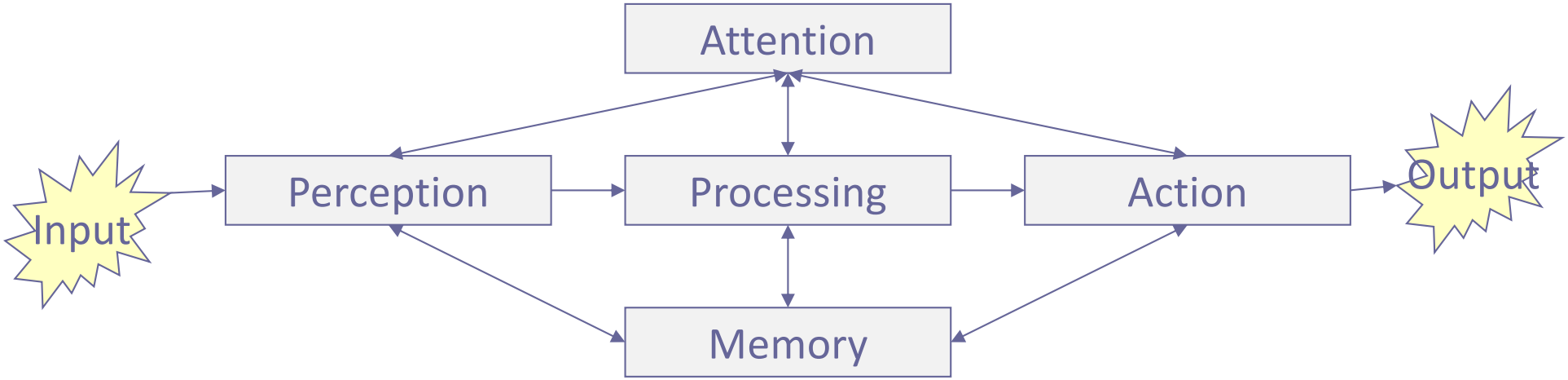
Storage (memory)

- Sensory memory
- Short-term memory
- Long-term memory

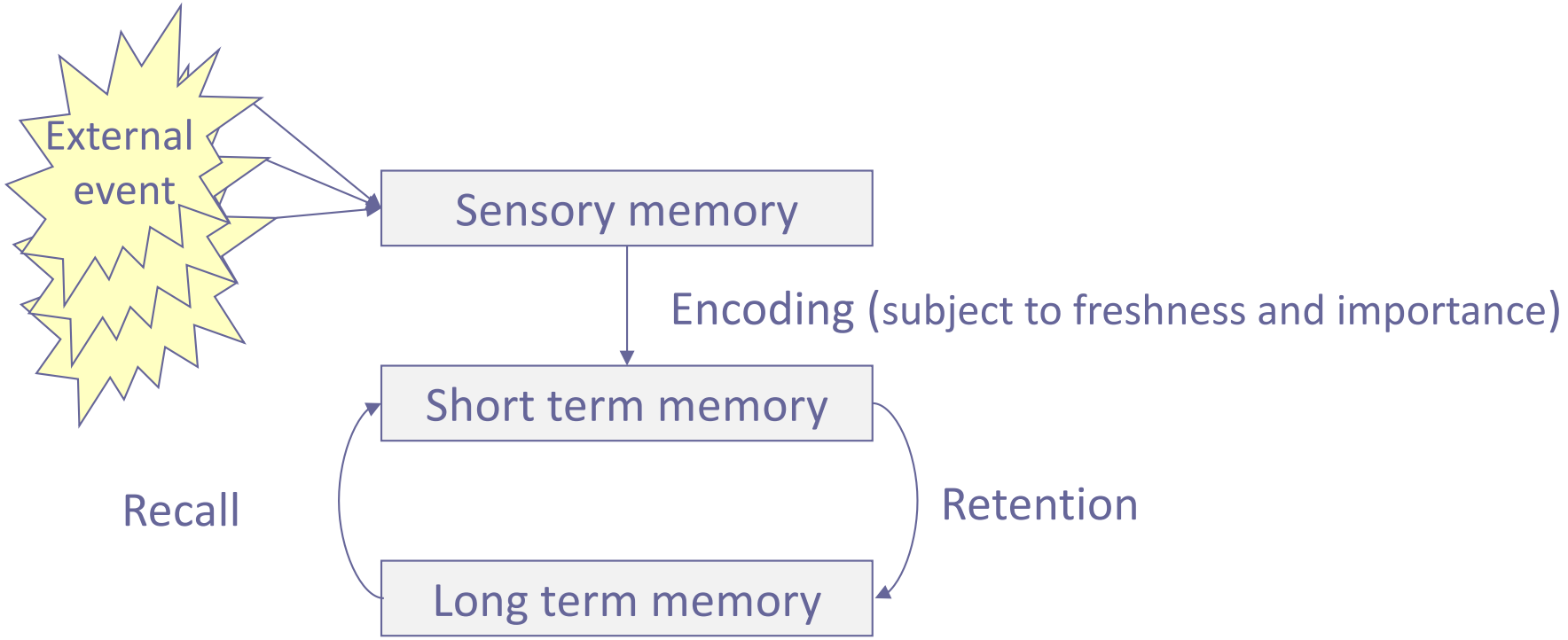
Processing (reasoning)

- Reasoning
- Learning
- Problem-solving
- Errors

Cognition



Learning



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Perception

Input

More than five:

1. Eyesight
   - Perception of light, shapes, colors
2. Hearing
   - Perception of sound waves
3. Touch
   - Termoreceptors (perception of temperature),
   - Nocireceptors (perception of pain)
   - Meccanoreceptors (perception of pression)
   - Wide differences in risolution and precision in different areas of the body
4. Taste
   - Chemical, termal and physical analysis of objects through sensors places on the taste buds and mouth membranes
   - N.B.: The tongue is five times more sensible to temperature and pression than fingertips

Input (2)

5. Smell
   - Chemical and tactile analysis of particles suspended in air performed by nasal membranes
6. Proprioception or kinestesia
   - Awareness of the position of the body and its parts wrt external space and other parts.
   - There are six types of specific receptors in various parts of the body, from muscles to tendines to the skin.
   - Cfr. *The Man Who Mistook His Wife for a Hat*, by Oliver Sacks, 1985 (tr. It: L'uomo che scambiò sua moglie per un cappello, Adelphi, 2008)
7. Balance
   - Awareness of the center of gravity of the body and of the speed and direction of movement.
   - A complex sense that is based on sight, proprioception and a specific set of receptors in the vestibular system (ear)

Eyesight (1)

Without a doubt, the most important source of external data for human beings.

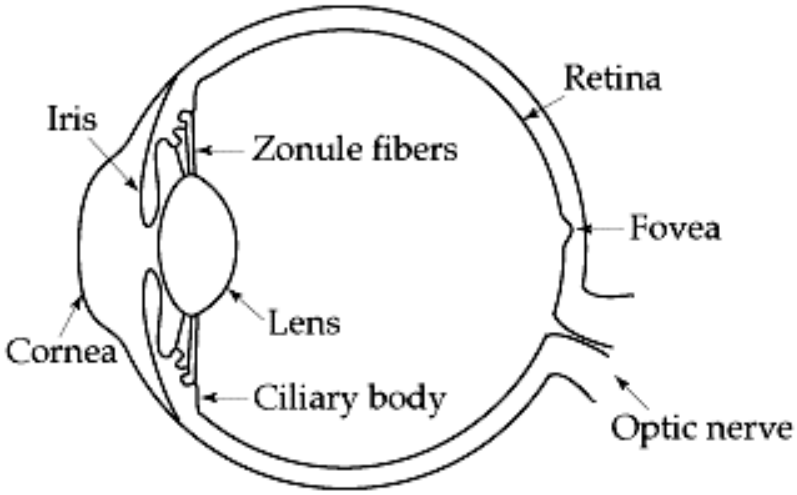
Two stages of the visual perception, each with specific characteristics:

- Physical perception of the visual stimuli by the eyes
- Further processing of the data by the brain

Fundamental aspects of human eyesight:

- Specialized hardware for movements, colors, brightness
- Pre-processing of fundamental shapes in the eyes, post-processing and sense-making in the brain
- Stereo vision provided by both eyes helps in computing distances and improves in the interpretation of the perceived data.
- Much is still in the processing of the image, still.

Eyesight (2) – Perception of light



The light is reflected onto objects of the real world and gets into the eye

The cornea protects the internals of the eye from external agents (air, dust, etc.) and acts a fixed focus lens, sending the light to the lens, which can focus instead.

The iris (iride) is a muscle controlling the pupil (the hole of the eye) thereby controlling the quantity of light entering the eye.

The lens send the image (upside down) to the back of the retina, where sits the photoreceptors.

The fovea is the exact focalization point of the image.

The junction between the retina and the optical nerve is almost without receptors and is called blind point (punto cieco).

Eyesight (3) - Photoreceptors

There are four types of photoreceptors:

- Rods (bastoncelli), spread all over the retina, very sensitive to the quantity of light and allow a fairly good night vision. They are not sensitive to colors and are easy to saturate (glare – abbagliamento)
- Cones (coni) are mainly placed in the fovea, and are very sensitive to the colors. They are not activate when the quantity of light is low, hence we have a limited perception of colors at night)
- X-Ganglion: mostly in the fovea, are dedicated to the pre-identification of visual patterns
- W- and Y-Ganglion: are everywhere and more densely in the external part of the retina, and are dedicated to the pre-identification of movement. This allows to perceive movement at the back of the eye much faster even without recognizing the shapes.

Eyesight (4) - Distance, depth, brightness

Perception of distance:

- We cannot perceive objects lesser than 0.5" of an arc
- Closer objects appear larger than farther objects.
- Nonetheless they appear to be constant even when the distance increases (the brain compensate for the loss of details)

Perception of depth

- Stereoscopic vision is caused by the comparison of the small differences in the perceived sitmuli of the two eyes. This gets processed to give an impression of depth.
- Other hints come from perception of overlapping, and familiarity with the perceived objects.

Perception of brightness (brillantezza)

- Brightness is the subjective perception of the quantity of light. It is different from the objective quantity of light emitted by a body (luminance (luminanza)
- Contrast is the difference in luminance between an object and its background
- Flicker: the perception of a light switching on and off, perceivable up to 50 Hz, but in greater frequencies with high luminance or in the peripheral vision.

Eyesight (5) – Perception of colors

Perception of color

- Colors is the cones' job, they are sensitive to three colors (red, green and blue)
- Due to their relative densities, colors are best perceived in the fovea and worse in peripheral vision.
- Blue receptors are considerably lower in quantity, so we are less sensible to shades of blu.
- Human beings can distinguish about 150 different hues (which is the wavelength of the reflected light), for a total of about 7 millions of colors when we consider intensity (color luminance) and saturation (presence of white in the color). Separately identifiable colors are only 10-20. There is no difference in color perception between males and females.

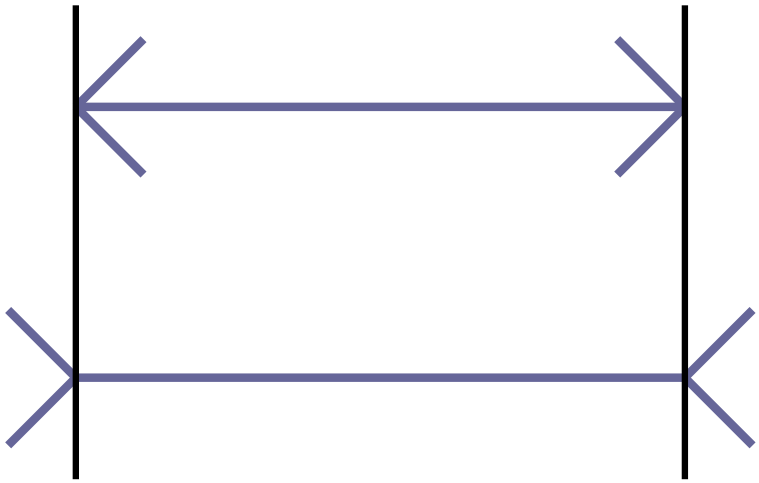
Color blindness (daltonismo)

- About 8% of males and 1% of females have a genetic deficiency in the functionality of cones, that makes colors hard to distinguish.
- A lack or disfunction in either green or red cones makes the other provide for these wavelength instead, causing confusion between these colors.
- Fairly rarer is a deficiency in blue cones, and even rarer the total lack of function in all cones (black and white color blindness)

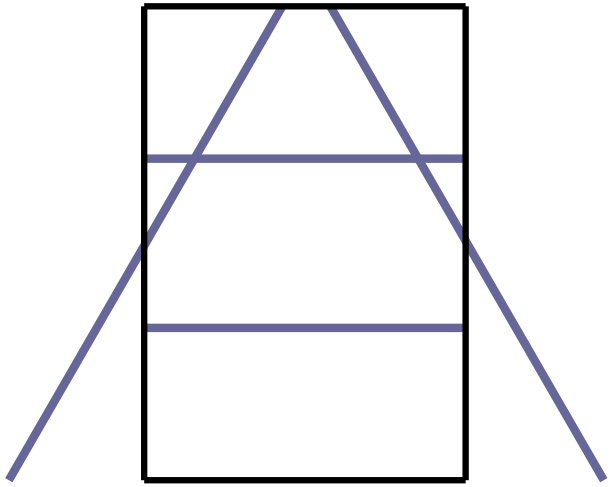
Eyesight (6) – Image processing

Image processing

- Image processing generates concepts that can be interpreted by the brain. Most of it is based on perception of patterns and expectation.
- These allow to provide stability in moving images and when we move wrt images.
- Optical illusions are usually bad activations of patterns or expectations.



Muller-Lyon Illusion



Ponzo illusion

Impact of experience in vision

What can you see in this image?

Can you see a dalmatian dog sniffing the ground?

Vedete un cane dalmata che annusa il terreno?

Expectation in perception

In the following image, look for scissors.
Nell'immagine seguente, cercate delle forbici.

What color were the scissors? Di che colore erano le forbici?

Did you notice a screwdriver? What color was it?
Avete notato un cacciavite? Di che colore era?

Structuring vision: the Gestalt principles

Early XX Century: the perceptual system forms a percept (gestalt – or shape in German) independent of the parts.
According to Kurt Koffka, "The whole is ***other*** than the sum of the parts"

Proximity

- Objects/events are closer in either space or time

Similarity

- Objects/events share attributes or properties

Continuation

- Objects are organized around a continuous and foreseable curve.

Closure

- Separate objects/events form a complete and recognizable figure

Simplicity

- Objects/events have shapes and structure that simplify their perception

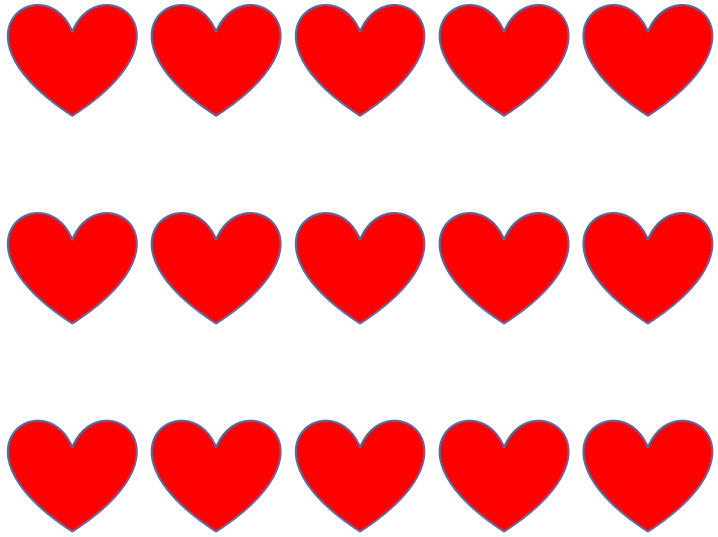
Figure/background

- Focus means identifying a figure as preminent and treating the rest as background.

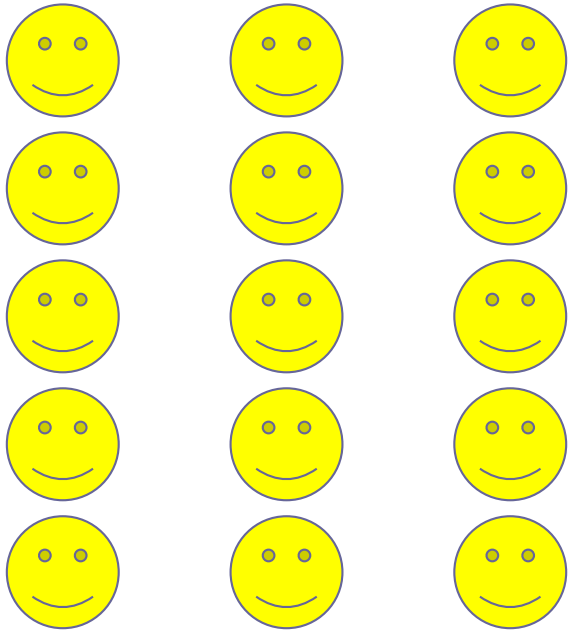
Common destiny

- Object behaving similarly have a common destiny

Proximity

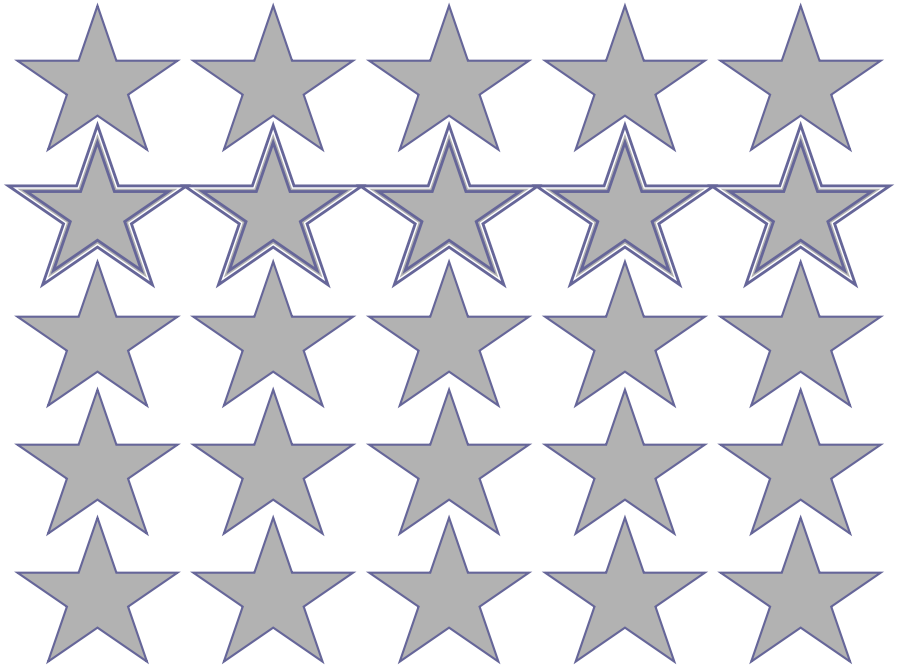


Organized in rows

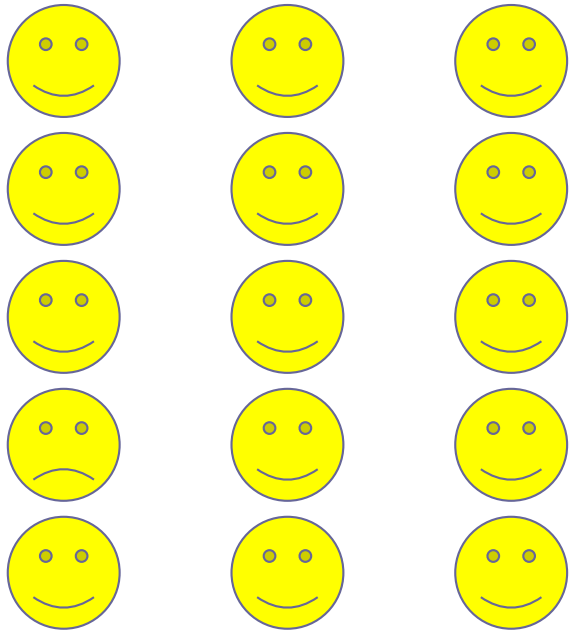


Organized in columns

Similarity



Similarity creates groups



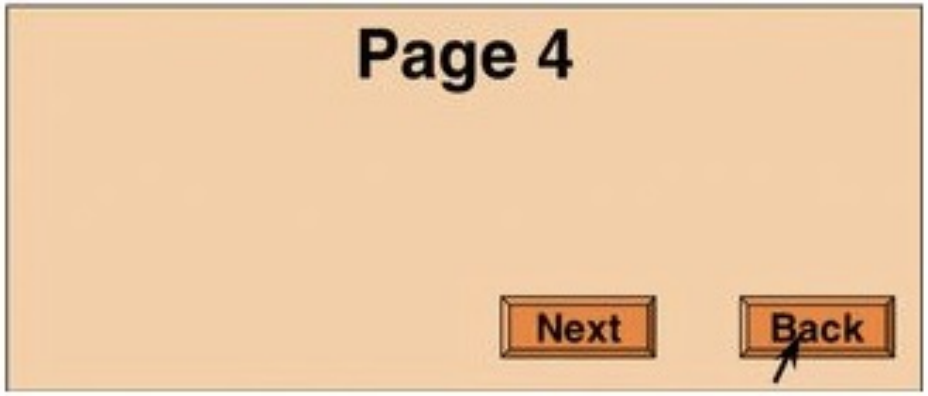
Similarity hides differences

Continuation

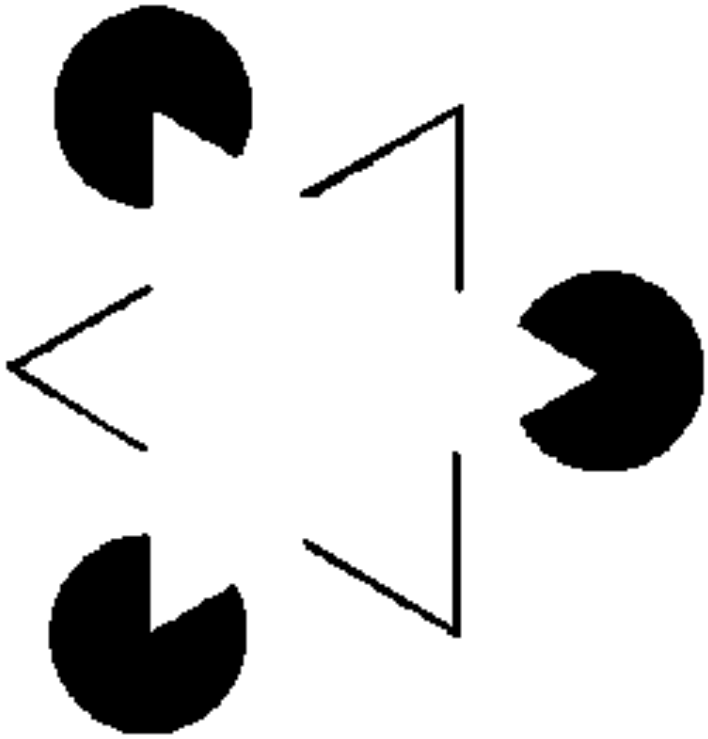
Continuations allows to fill in missing parts

Continuation allows to group separate objects in a single one

Error: not using continuation



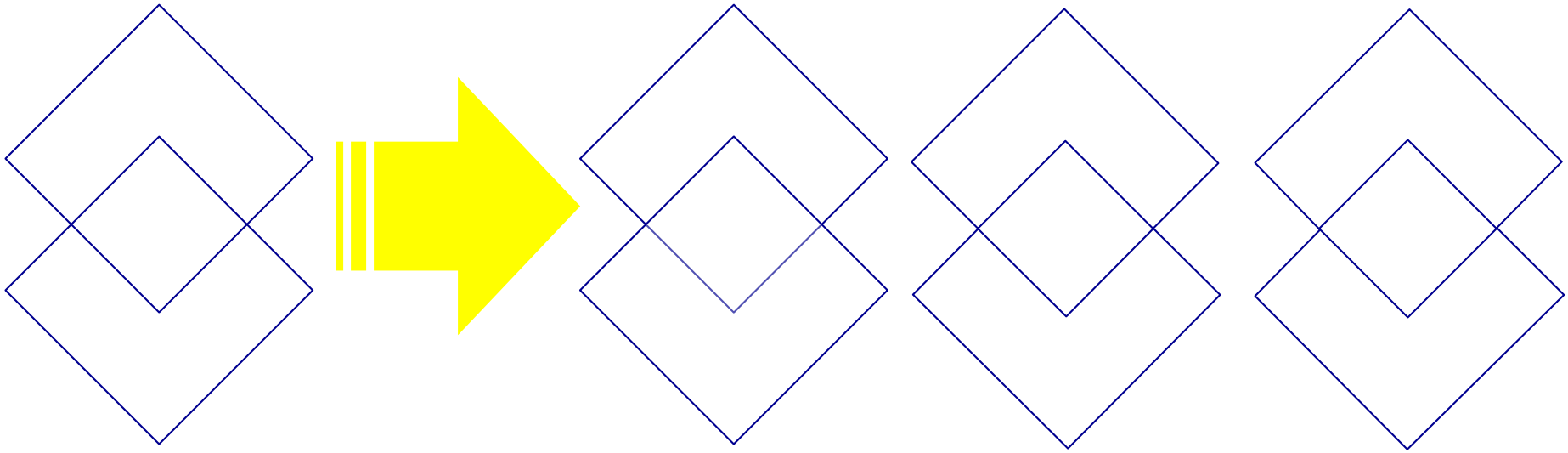
Closure



Closure changes
the nature of shapes

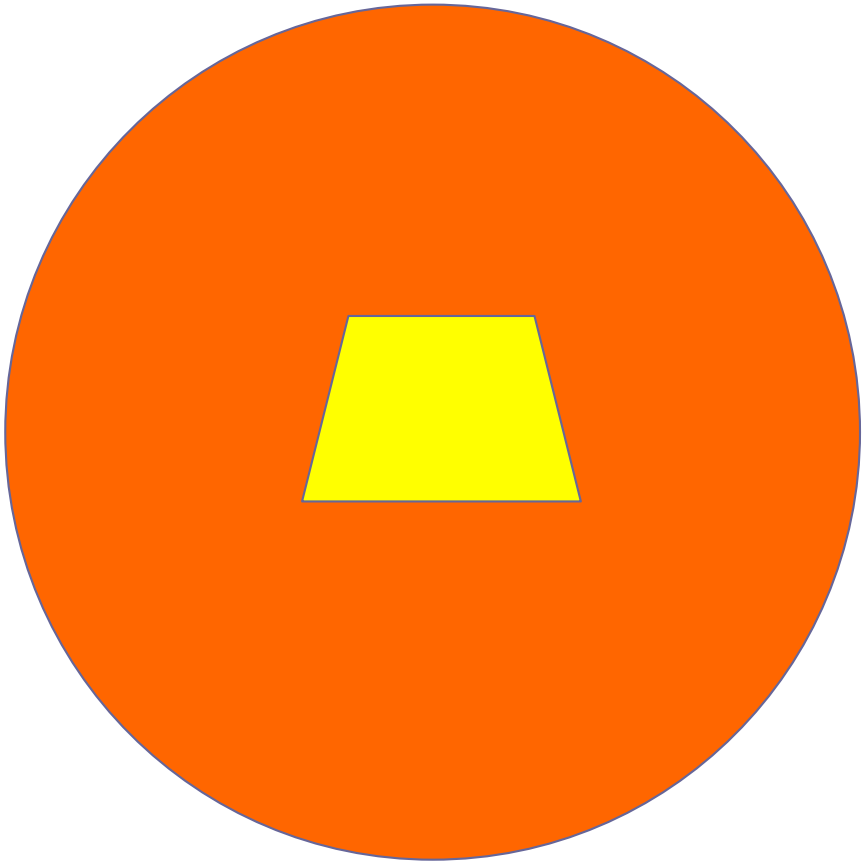
Closure provides different
interpretations for the
various parts of an image

Simplicity

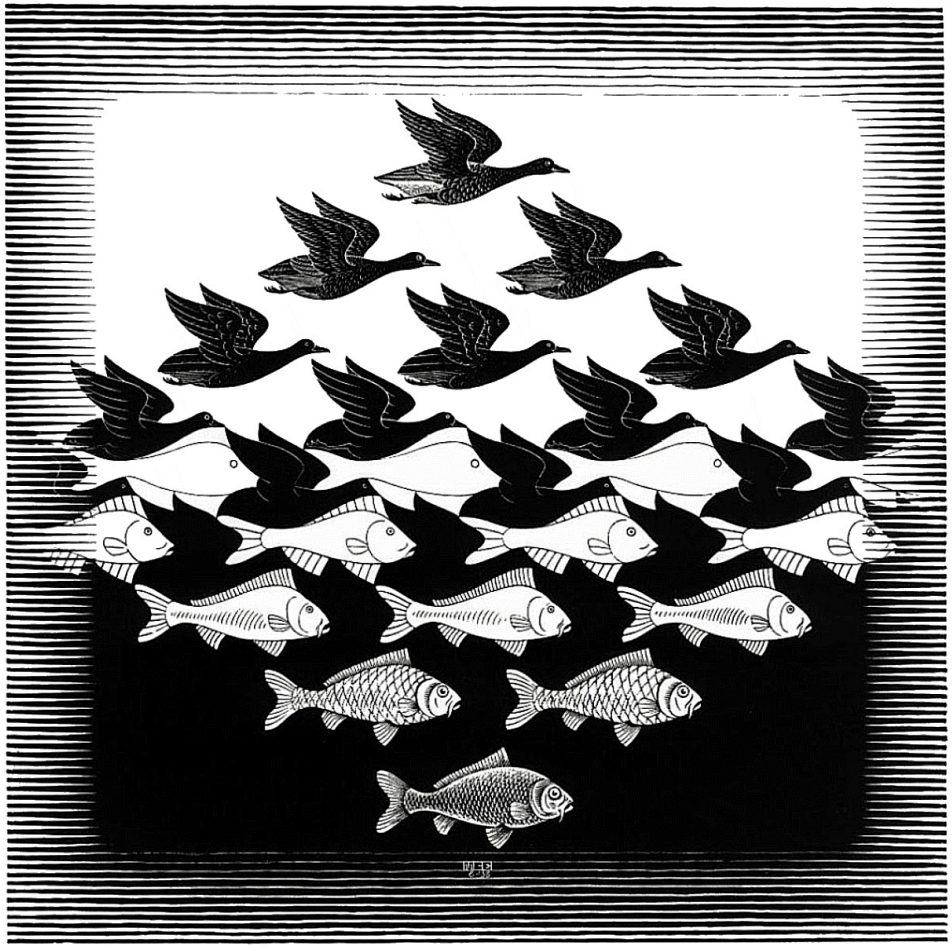


We tend to prefer the simplest explanation

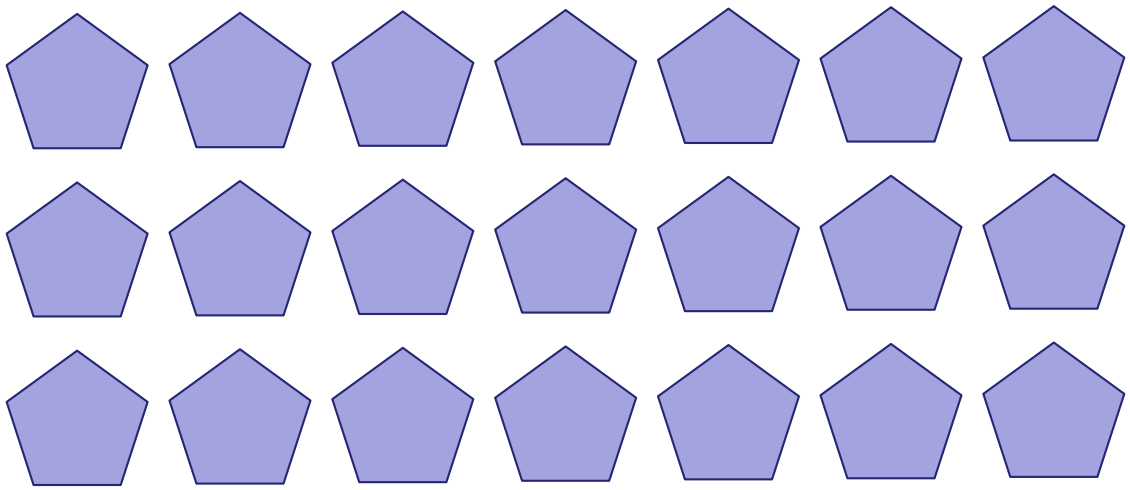
Figure / background



The larger image is the background, the smaller image the figure



Common destiny



Objects behaving similarly are
perceived as grouped

Eyesight (7) – processing of text (1)

- Three separate phases
  - Input of the visual perception of the text
  - Decoding of the word or words based on reference language
  - Sintactic and semantic analysis of the text
- During the visual perception of the text
  - 6 % of time in burst movements of the pupil, both forward and backward.
  - 94 % of time in fixed position (processing time)
  - Complexity of text is proportional to the number of regression (backward movements) of the eye.
- Reading does not mean identifying individual letters or words
  - Recognition time for individual letters, whole words or simple sentence is identical.
  - The shape of the words affects directly the reading speed: unfamiliar fonts, uppercase text and unknown languages slow down reading considerably.

Eyesight (7) – processing of text (2)

Aids and obstacles to reading

- Literate adults read about 5.5 syllables per second
- Font sizes between 9 and 12 points are equally readable, slower if larger or smaller.
- Line widths between 6 and 14 cms are equally perceivable without speed differences
- Reading on a computer screen IS slower
  - Longer lines
  - Fewer words per screen than a page
  - Text orientation
- Negative contrast (dark text over light background) reduces luminance and therefore has greated contrast than positive contrast. Yet it is more prone to flickering.

Problems with text processing

Sopra la panca la capra campa
Soffio la panca la capra crepa

Ttertarné tnenirti etnoraro in Tnerto
tttui e ttertarné tlenderrolatto

La vispa Teresa avea tra l'erbetta

Problems with text processing

The grass is always greener on the othen side

Yuo cnaont mkae an otelem wtiuhot bakrineg a fwe eggs

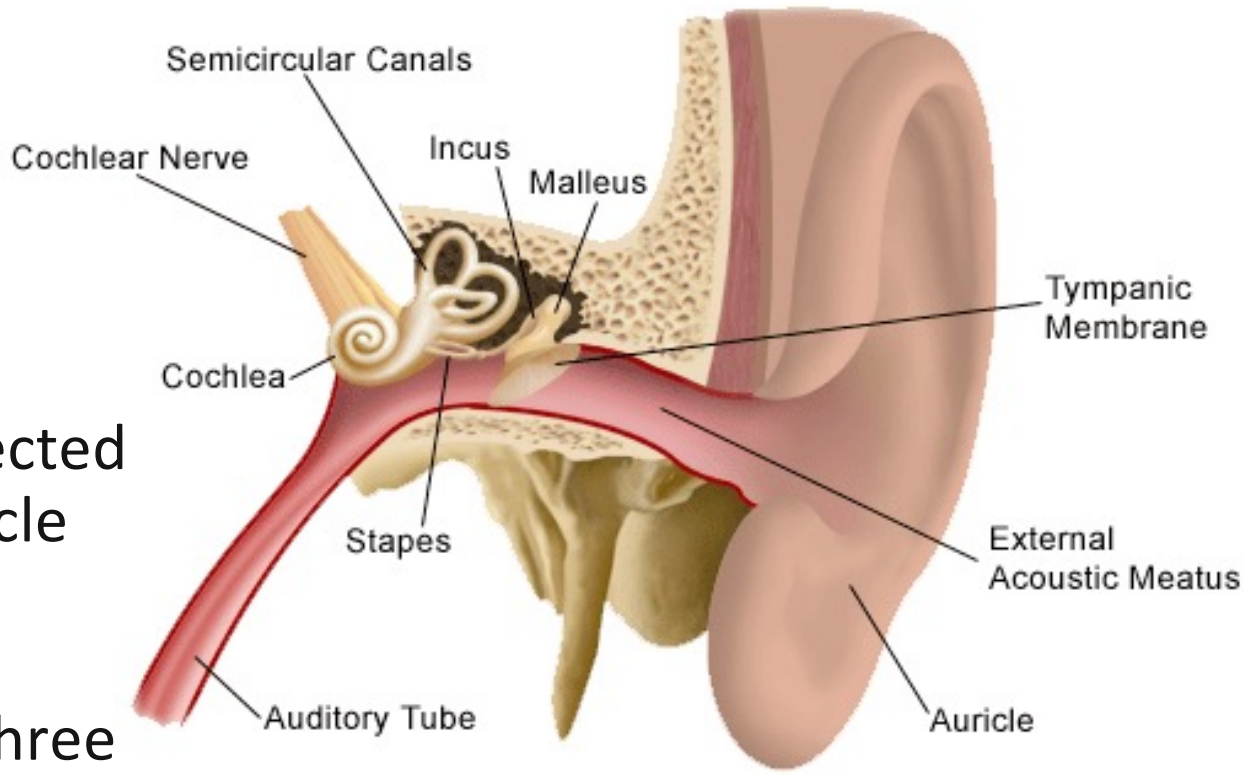
An apple a day keeps the doctor away

Designing for reading

- Avoid uncommon or unfamiliar terms
- Avoid decorative or uncommon fonts, small fonts, noisy backgrounds
- Organize the text in blocks of lesses than 14 cm, so that the head does not have to move to read them.
- Organize numbers in groups, dates in blocks, texts in hierarchical structures allowing for the general structure to be perceived before the actual content.
- Avoid centered text
- Avoid redundant text
- Minimize the need to read long texts
- Uppercase text is NOT appropriate for longer reads. Use them only in titles.

Hearing (1)

Apparently of lesser importance than sight, provides an enormous amount of information about our surrounding.



The ear receives air vibrations that are collected and aplified by the auricle (padiglione auricolare) hitting the eardrum (timpano) that moves three little bones: malleus, incus and stape (martello, incudine e staffa) that move a jelly-like substance in the cochlea (or inner ear), which activates tiny hair cells trasmitting information to the auditory nerve and to the brain. The Eustachian tube is used to regulate internal and external pressure of the ear.

Hearing (2)

Characteristics of sounds:

- Pitch (perceived frequency of the sound)
- Loudness (perceived sound pressure)
- Timbre (perceived sound quality)

Human ear can perceive frequencies between 20Hz and 15000 Hz.

Lower frequencies are perceived with the bones, not the ear.

Resolution changes depending on frequencies

We can perceive direction and movement of sound through the stereophonic perception of the two ears.

Hearing is fundamentally based on filtering mechanisms that allow to isolate that parts of the perceipt from the surrounding noise (***cocktail party effect***)

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Storage

Memory

In the Sixties a specific theory for memory was proposed based on a layered model:

- Sensory memory
- Short-term or Working memory
- Long-term or permanent memory

We don't know if they are separate, nor how they interact. We use them as a model with a clear mapping to computer hardware more than as a guide to the actual working of the human mind.

Sensory Memory

Specificity

- Iconic memory for visual stimuli
- Echoic memory for aural stimuli (used for stereophonic comparison, but also for retention of the stimulus)
- Tactile memory for touch
- Etc.

Persistence

- Stimulus is maintained for a few tenth of second (about 0.5 sec for vision) and is continuously rewritten.
- Only a minimal quantity of data is maintained, most of it is lost immediately or during data processing.

Attention

- This is the fundamental mechanism for filtering out unneeded data.

Continuity

- Continuity of perception is fundamental for time flow awareness and connection to reality.
- Interruptions or interferences generate deja-vu (paramnesia)

Designing for sensory memory

Reduce mental load needed to interpret sensory stimulus

- Few simple elements, well differentiated, solidly placed in the overall interface.

Use systematically the theory of Gestalt to help the structuring of the perceipt.

- Allow for grouping of connected pieces, make differences evident when they are meaningful, hide differences when they are not.

Short Term Memory (1)

Also known as *working memory*

This is where the data relevant for the tasks currently in execution are maintained and processed.

It uses about 7 ± 2 "chunks" or blocks (possibly structured)

They are sensorily modal, and allow grouping.

For example:

5 2 1 4 7 6 5 1 2 1 0

055 456 712 65

Short Term memory (2)

The short-term memory is always full.

If a new chunk of information is stored only by replacing a previous one: something needs to be removed.

Persistence is of about 15 seconds.

Persistence can be increased with auditory repetition

Retention is amplified by importance first, and freshness next.

Designing for short-term memory

Reduce the mental load necessary to maintain dialog context and consistency:

- Have fewer chunks (complex if needed) to retain in mind (7±2 distinct elements)
- Help recover disappeared chunks from the visual context
- Help retain greater quantity of information through grouping

Long Term Memory (2)

Our long-term memory is organized in:

- *Episodic memory*: recording of events and experiences is done in a serial way.
- *Semantic memory*: recording of facts, concepts and ability learnt in the past

Long term memory is never a complete recording of the perceipt, but a post-processing of the relevant parts with heavy filters on it.

Eidetic memory

The remembering with a large number of details (remembering the perceipt rather than its processing)

Happens mostly with pre-school children, extremely rare with adults.

- cfr. "Funes el memorios", (*en: "Funes the memorious", it: "Funes, o della memoria")*, in J.L. Borges, *Ficciones*, 1944

Except in such pathological cases, the adult brain has learnt to never retain more details of the perceipt than an extremely simplified form of it.

Eidetic memory: an experiment

Question:

How many colored bands are in the tail of the cat?

Quante strisce colorate ci sono nella coda del gatto?

The Cheshire cat (Stregatto)
(from Alice in Wonderland, Disney, 1950)

Long Term Memory (3)

Retention is obtained through processing, and we do not know neither limits nor duration of storage.

Organization is hierarchical and associative: most probably it can be mapped as a semantic network connecting concepts in categories and subcategories.

Disconnected concepts (without logical connections to other facts of our knowledge) are harder to retain than connected ones

Abstract concepts are harder to retain than concrete concepts

Concepts with a higher level of emotional connection (not necessarily personal) are easier to retain than dry ones

Long term memory: an example

3 sets of 8 words of the same type: six nouns, one adjective, 1 adverb

- **Language Past Cold Age But Great Faith Ideas**
- **Never Tree Cat Church Carpet Red Flame Head**
- **Hunter Gun Wolf Shot Dead Now Sheep Field**

Verbs represent change.

They create a narrative with temporal and sequential connections between the words,

This makes it MUCH simpler to retain concepts

- **Language Past Makes Cold Age But Great Faith Builds Ideas**

Long Term Memory (4)

Categorization is not neutral and not only on semantic motivation. Temporal and emotional coloring play an important role.

Interference

- accessing a memory can cause access also to a different one completely disconnected from a logical point of view.

Forgetting *Two theories:*

- Decay (decadimento): memories not frequently accessed slowly but naturally decay and disppear – connected with "tip of the tongue effect" (effetto punta della lingua)
- Interference: retention of new information naturally and immediately replaces an older similar information (ATM codes)

Memory works better at recognizing than recalling

- Retrieving a written note with the old code will make you immediately recognize the number and its meaning.

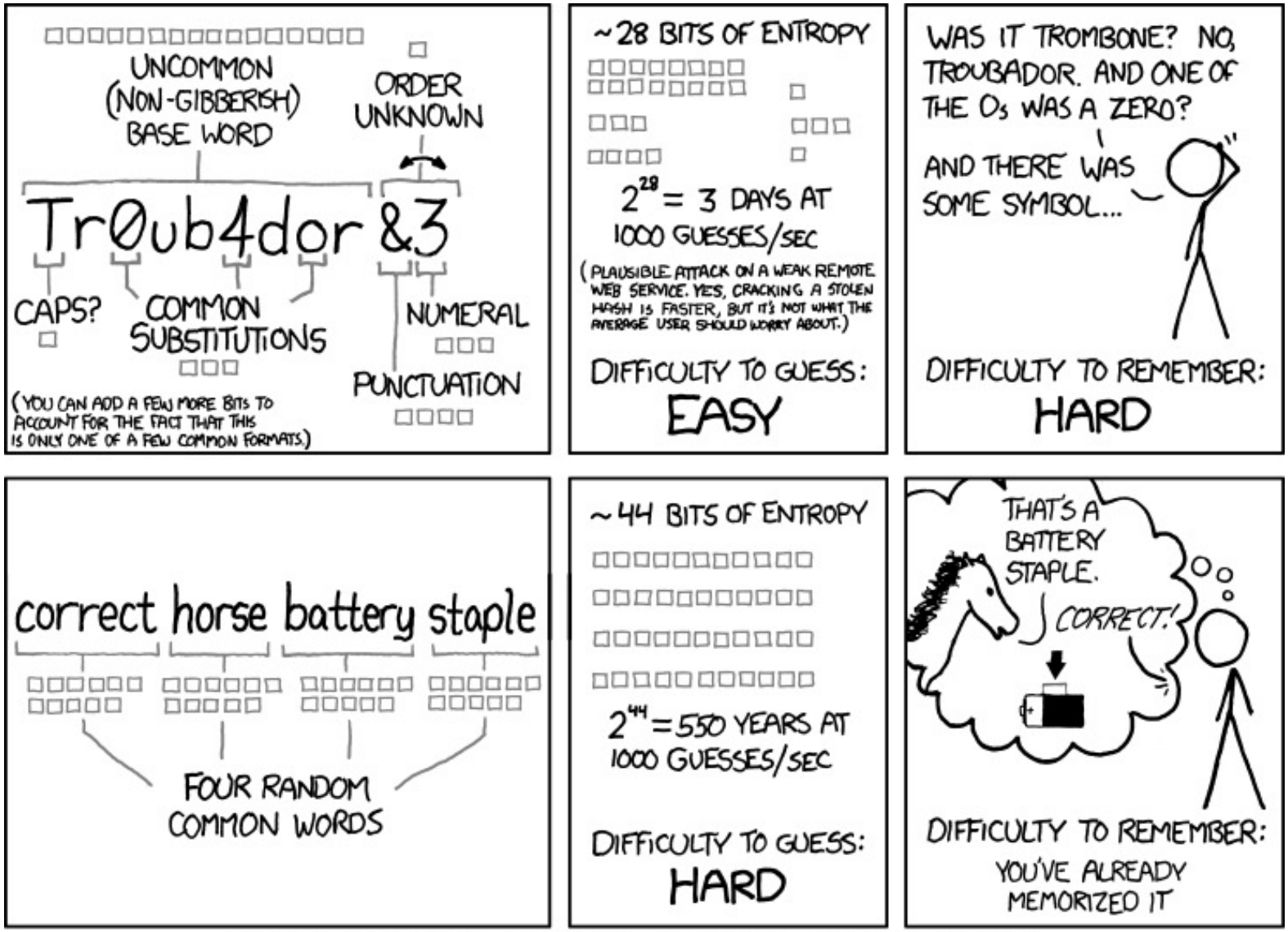
Designing for Long Term Memory

- Never rely on plain memory of facts
- Try to convey a narrative in the sequence of steps. Alternatively, iconic or visual memory is better that episodic or punctual memory
- Allow for easy abstraction to allow for simpler chunks to be retained.
- Use verbs for actions and nouns for concepts. Create a narrative for the interaction

Additional reflections

- Looking and choosing is easier than remembering and typing
- Images are easier to recognize than words
  - Thumbnails are more useful that text descriptions for images
- Visibility must be proportionl to importance and frequency of use of the function
- Use visual aids to remind the user where he/she is
- Make authentication data easy to remember

An example


UNCOMMON (NON-GIBBERISH) BASE WORD
ORDER UNKNOWN
Tr0ub4dor&3
CAPS?
COMMON SUBSTITUTIONS
NUMERAL
PUNCTUATION
(YOU CAN ADD A FEW MORE BITS TO ACCOUNT FOR THE FACT THAT THIS IS ONLY ONE OF A FEW COMMON FORMATS.)
~28 BITS OF ENTROPY
2^28 = 3 DAYS AT 1000 GUESSES/SEC
(PLAUSIBLE ATTACK ON A WEAK REMOTE WEB SERVICE. YES, CRACKING A STOLEN HASH IS FASTER, BUT IT'S NOT WHAT THE AVERAGE USER SHOULD WORRY ABOUT.)
DIFFICULTY TO GUESS:
EASY
WAS IT TROMBONE? NO, TROUBADOR. AND ONE OF THE Os WAS A ZERO?
AND THERE WAS SOME SYMBOL...
DIFFICULTY TO REMEMBER:
HARD
correct horse battery staple
FOUR RANDOM COMMON WORDS
~44 BITS OF ENTROPY
2^44 = 550 YEARS AT 1000 GUESSES/SEC
DIFFICULTY TO GUESS:
HARD
THAT'S A BATTERY STAPLE.
CORRECT!
DIFFICULTY TO REMEMBER:
YOU'VE ALREADY MEMORIZED IT
THROUGH 20 YEARS OF EFFORT, WE'VE SUCCESSFULLY TRAINED EVERYONE TO USE PASSWORDS THAT ARE HARD FOR HUMANS TO REMEMBER, BUT EASY FOR COMPUTERS TO GUESS.

Attention

Attention is the selection of one or a few of the sensorial stimuli that reach us.

Attention can be focused (writing) or divided (driving while talking or listening to the radio)

Cocktail party effect: our ability to filter out (exclude) most part of the stimuli even from one sense only.

The task decides what to focus on. Expectations impact on attention.

Attention is modal: unexpected events or facts out of modality are a source for distraction

Cognitive aids for maintaining attention

Designing for attention

- Reduce cognitive load
  - Even if this increases the quantity of atomic actions to perform
- Drive users to choose faster or easier action paths
- Show clearly the state of the system and the progress level in the completion of a task
- Make the system familiar
- Let the computer do the computations (e.g.: totals)
- Use familiar terms.

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Processing

Reasoning (1)

Reasoning is how we use knowledge we already have to generate conclusions on the event we are focusing.

We use reasoning to generate new information and solve problems in our everyday life.

This happens in a semi-conscious mode: sometimes we reach a result or a solution without really being aware of the process followed to get there.

At least three different types of reasoning:

- Deductive reasoning
- Inductive reasoning
- Abductive reasoning

Deductive reasoning

Starting from a general assumption and a concrete case, we obtain a precise conclusion

GIVEN THAT
All breathing people are alive
John is breathing,
THEN
John is alive.

$$\frac{\forall\, x \in \text{People},\ \textit{breathes}(x) \Rightarrow \textit{alive}(x) \qquad \textit{breathes}(\text{John})}{\textit{alive}(\text{John})}$$

Sillogism is the most famous of deductive reasoning tools

We are not always good with deductive reasoning, especially in presence of false or partial assumptions.

GIVEN THAT
Some people are babies
Some babies cry
CAN WE DEDUCE THAT
Some people cry?

$$\frac{\exists\, x \in \text{People},\ x \in \text{Babies} \qquad \exists\, y \in \text{Babies},\ \textit{cry}(y)}{\exists\, z \in \text{People},\ \textit{cry}(z)}$$

GIVEN THAT
Some Bolognese are students
Some students are foreigners
CAN WE DEDUCE THAT
Some Bolognese are foreigners?

$$\frac{\exists\, x \in \text{Bolognese},\ x \in \text{Student} \qquad \exists\, y \in \text{Student},\ \textit{foreigner}(y)}{\exists\, z \in \text{Bolognese},\ \textit{foreigner}(z)}$$

Inductive reasoning

Starting from many homogenous cases I produce (induce) a general rule (*inference* or *generalization*)

All the elephants I have seen have a trunk (proboscide)
THEREFORE
All elephants have a trunk

Inference is unreliable and easy to disprove (you only need to show an elephant without a trunk)

Furthermore it cannot be completely proved unless we can examine systematically all cases

Yet, it is the usual method to generate new rules in our daily life and in science.

Abductive reasoning

Given a case (for which many rules can be applied), we choose the best rule that applies to the case

John is driving too fast
John drives fast when he's drunk
THEN
John is drunk

This mechanism is also imperfect: many rules could apply and there could be unknown rules that could apply.

John could be having an emergency

Additionally, an unjustified assumption with abduction is that a rule exists to explain the case, and we only need to identify it.

In computer systems, we often assume that something that happens on the screen is derived from the action we have just performed, and therefore if the two facts are disconnected, this creates confusion and error.

Problem solving

Finding a solution to a new or unfamiliar problem.

Humans are able to adapt any knowedge they have to new situations

- Behaviorism (comportamentismo): end of XIX Century, problem solving is based on either applying existing rules, or by trial and error, exploring possible solutions until a good one is found.
- Gestalt theory (mid XX Century): problem solving is based on application of existing rules (reproductive approaches) as well as reflecting and restructuring the problem in different terms (productive approaches). Ex. Two ropes from ceiling
- Problem space theory ('70s): the problem is expressed as the search for a path inside a space where there is an initial state (the problem) and a final state (the solution), Possible desirable intermediate places are identified, and the problem solving is expressed as finding a path to a closer intermediate place, and then analysis is started again from the closer position. Each subproblem is analyzed looking for euristics, competencies and analogies.

Performances of human beings (1)

- Response times depend heavily on the type of stimulus
  - In particular, we respond much faster to sound than visual stimulus
- Compromises between speed and accuracy
- Automatic responses decrease in accuracy
- Repeated responses decrease in accuracy and speed
- Tiredness decreases speed and accuracy
- Action errors (imprecision) impact on performance as much as wrong decisions.

Performances of human beings (2)

Fitt's Law: The time necessary to reach a screen target with a pointing device is proportional to the distance and inversely proportional to the target's dimension.

$$T = a + b \log_2 \left(\frac{2D}{W}\right)$$

where:

- T: time to target
- a, b: costants to be determined
- D: distance of target
- W: dimension of target

Conclusions

Content of these slides

- Limits and constraints of human beings as devices
- Characteristics of I/O channels of human beings
- Types of Human memory and processing mechanisms
- Performances of human beings

References

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