Human

- Human Models, Senses and Memory
- Conceptual Model and Mental Model

Why Study Human?

We are the users

When we try to understand something, particularly new, we use a combination of

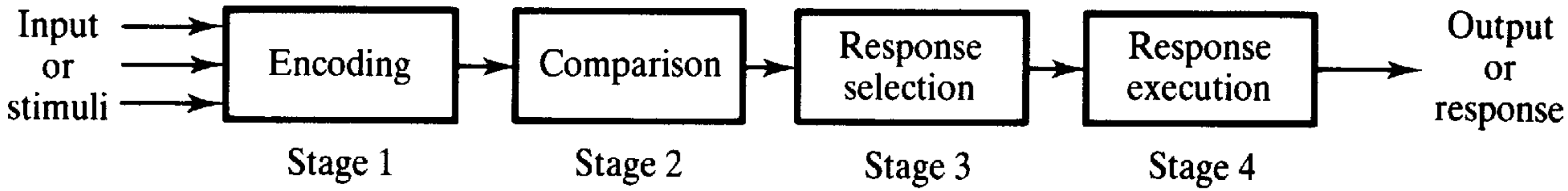
- What our senses (sight, hearing, touch, smell, taste) are telling
- Past experience
- Our expectations

e.g., When we browse a new Web, our past experience tells us that underlined blue text is supposed to be a link

e.g., When we are given a new product with buttons, we expect that it is operated by pressing the buttons

Human Model

Modelled as information processing system

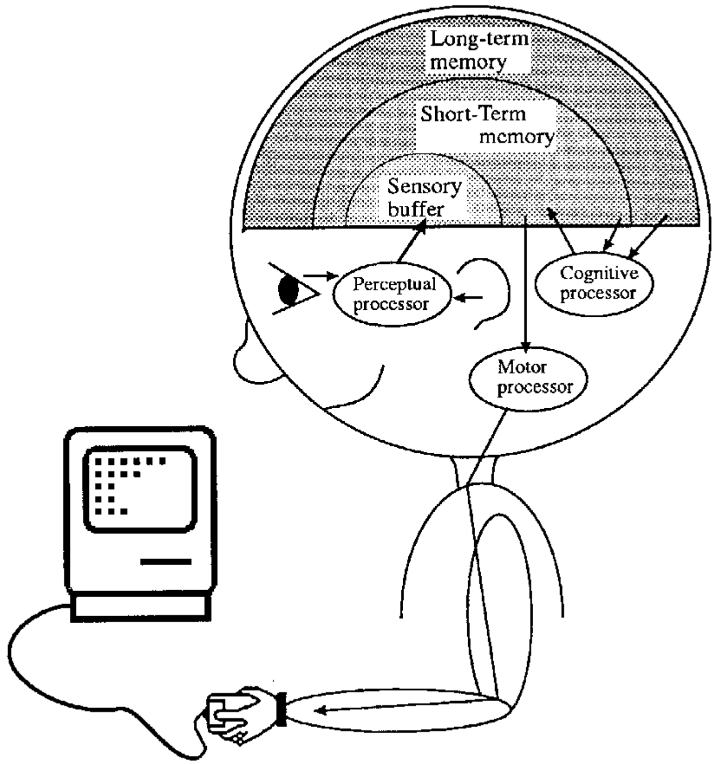


- Stage 1: encode information (sight, hearing, touch, smell, taste) from environment into internal representation
- Stage 2: internal representation of the stimuli is compared with the memorized representations in brain
- Stage 3 is concerned with deciding on a response to encoded stimulus
- Stage 4 deals with organization of response & necessary action

Human Model

Card, Moran & Newell's Model:

- Comprise 3 interacting systems:
  - Perceptual system consists of sensors & associated buffer memories:
    - Visual image store
    - Auditory image store
  - Cognitive system consists of short-term & long-term memories
  - Motor system carries out response formulated by cognitive system



Human Senses

The five senses are:

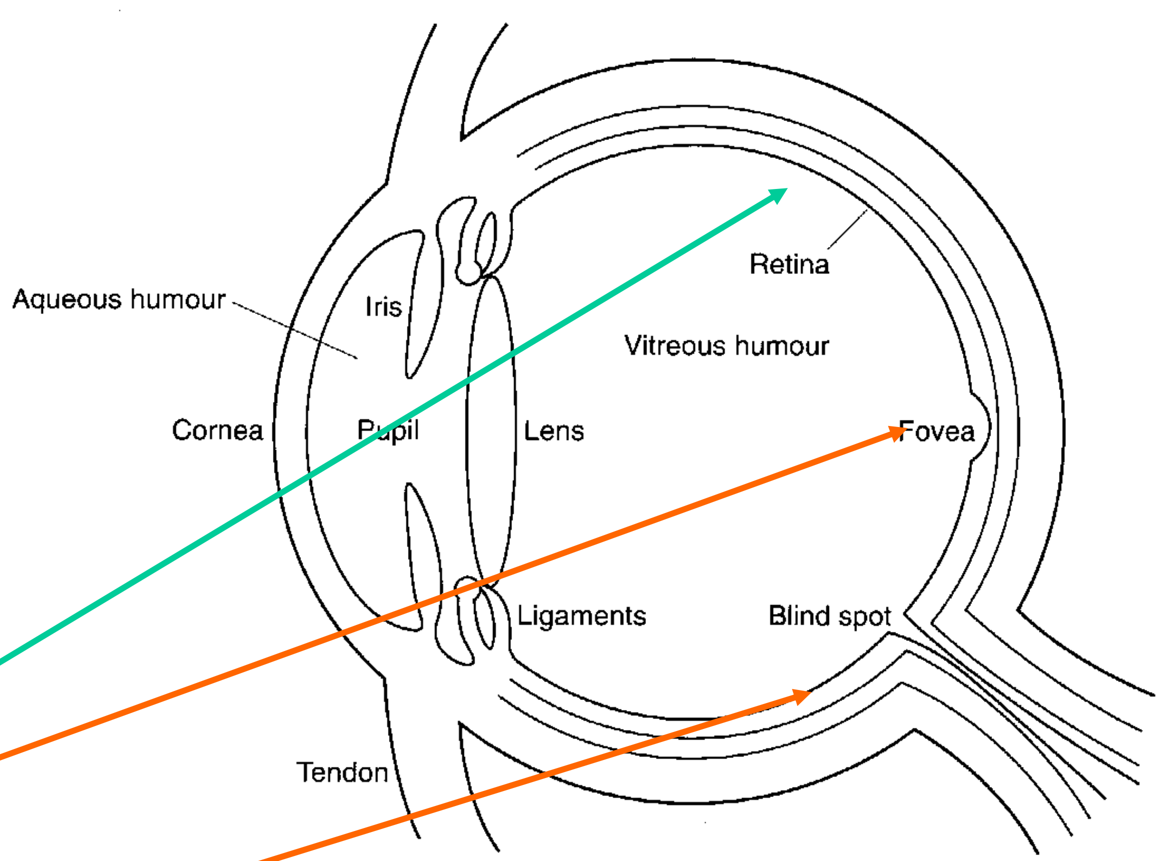
- Sight
- Hearing
- Touch
- Smell
- Taste

They can interact with computing systems:

Input to Human	Output from Human
Vision	Speech
Audition	Motor Control
Balance	Biometrics, e.g., fingerprint
Olfaction	
Touch	

Vision

- Eye
  - Mechanism for receiving light & transforming it into electrical energy
  - Light reflects from objects; their images are focused upside down on retina
  - Retina contains
    - Fovea: colour vision, pattern detection
    - Outer part: sensitive to light, movement detection



Vision

Design implication:

- A user concentrating on the middle of the screen cannot be expected to read text on the bottom line because outer part is not good for pattern detection

$\Rightarrow$ If we want a user to see an error message at the bottom of the screen, since the outer part is capable for change detection, the message should be flashing

Constructivism

A theory about vision is constructivism:

- Our brains do not create pixel-by-pixel images
- Our minds create, or *construct*, models that summarize what comes from our senses
- These models are what we perceive
- When we see something, we do not remember all the details, only those that have meaning for us

Design implication:

- Do not expect people "see" all the details of an interface because people filter out irrelevant information and save only the important ones

How many links are there on left hand side of http://www.cityu.edu.hk ?

Constructivism

Constructivist theory states that context plays a major role in what we see in an image

What do you see?

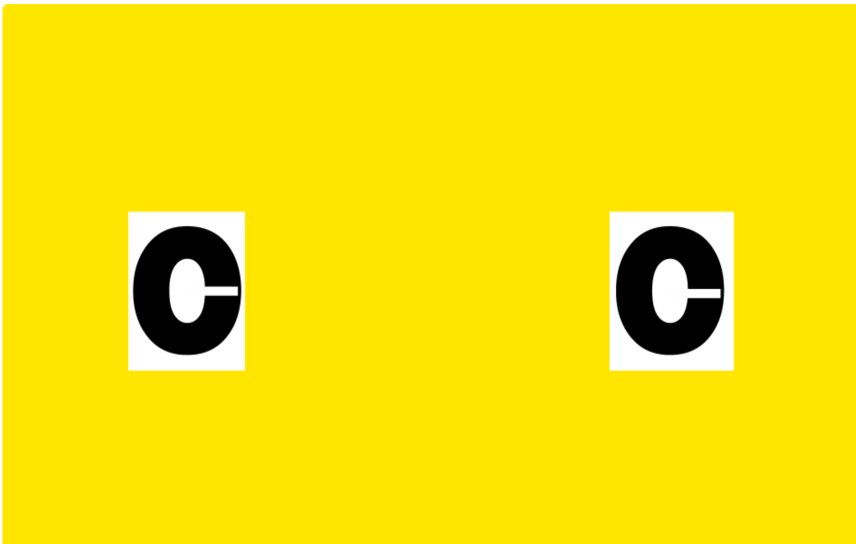
Constructivism

Why we cannot see it at first?

- The image is too blurry
- We had no idea what to expect because there was no context

Now we have context, we can recognize easily next time

Are these letters the same?

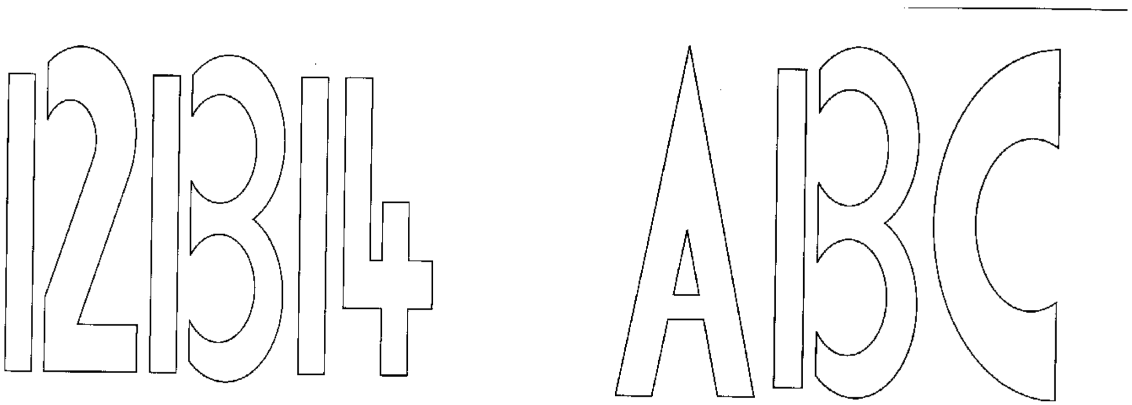


Constructivism

With context, the answer will be different:

Design implication:

- Context can help in resolving ambiguity



Constructivism

HEAD or HERO?

DEPARTMENT OF COMPUTER ENGINEERING & INFORMATION TECHNOLOGY http://www.it.cityu.edu.hk

IT FLASH

PROVIDING QUALITY EDUCATION AND INITIATING TECHNOLOGY ADVANCEMENTS

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PROF H YAN

MESSAGE FROM ACTING HEAD

In line with the role statement of CityU, the Department emphasizes applied research and application-oriented teaching. After a few years of endeavour, I feel grateful to see that our aspiration to transfer research achievements to the society has been realized. Last year, we obtained one patent and submitted six patent applications. Moreover, seven licensing agreements with telecommunication, Internet and software companies were signed because of the high industrial relevance and marketability of our applied research. May I give thanks to our industrial partners, colleagues and the University for their support in the course of opening up the applied research frontier. Here, I am with great pleasure to introduce to you some of our applied research work in the areas of 3G mobile entertainment and communication, security and monitoring, database management, computer graphics and pattern recognition. All of them are ready for commercialization or technology transfer in form of consultancy, contract research or licensing.

While we are extending our arm to the industry, we believe that we should also interact with the general public and bring our innovative and practical work to their knowledge. To this end, we have been organizing different activities like exhibitions, road shows and seminars to share our work with the public.

Apart from developing applied research, we are also devoted to education and particularly, its synergy with our applied research strengths. Our programmes stress hands-on experience and the independent ability to master and even pioneer the state-of-the-art technology. Coupled with solid theoretical foundation, our application-oriented education stimulates students' learning and creativity. Inside this newsletter, you can find some of our students' innovative work on the prevailing mobile technology. Soon, we will revamp our undergraduate programme to better equip students with professionalism and readily applicable technical skills in response to the needs of the society.

I hope you enjoy the reading, and look forward to your continuous support and advice!

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Constructivism

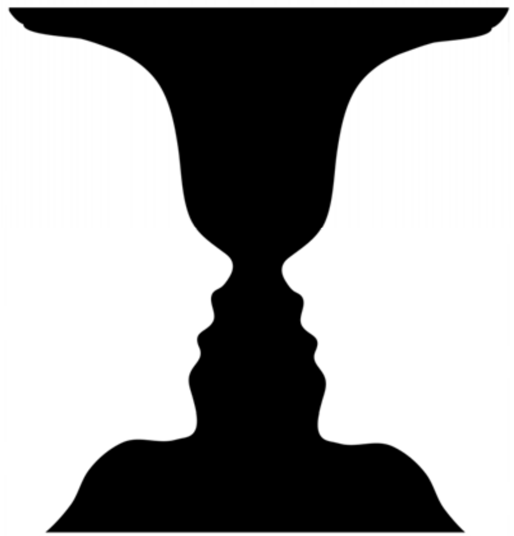
Another concept from constructivism: images are partitioned into

- Figure (i.e., foreground)
- Ground (i.e., background)

Sometimes figure and ground are ambiguous

Example:

A person who sells flowerpots may see a vase while a person who likes observing people's faces may see two faces



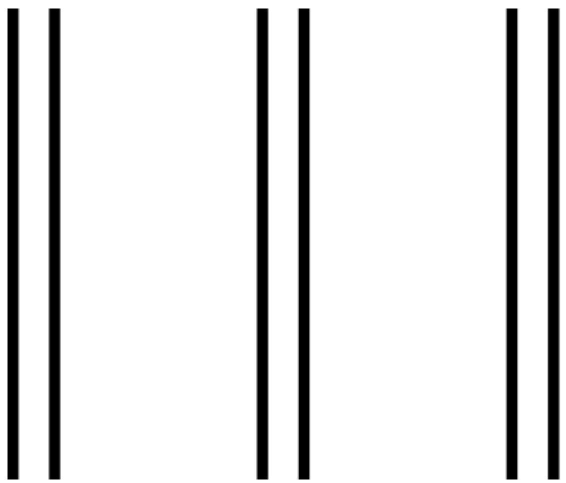
Gestalt Psychology

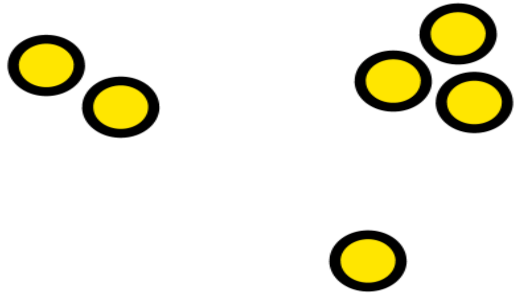
- Main idea: We do not see things in isolation, but as parts of a whole
- We organize things into meaningful units using
  - Proximity: we group by distance or location
  - Similarity: we group by type
  - Symmetry: we group by meaning
  - Continuity: we group by flow of lines (alignment)
  - Closure: we perceive shapes that are not (completely) there

Gestalt Psychology

Principle of proximity

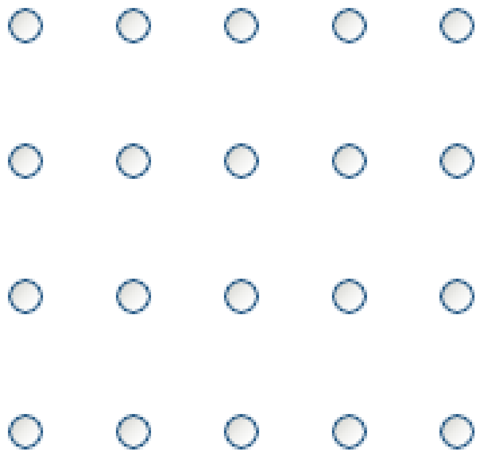
Example:



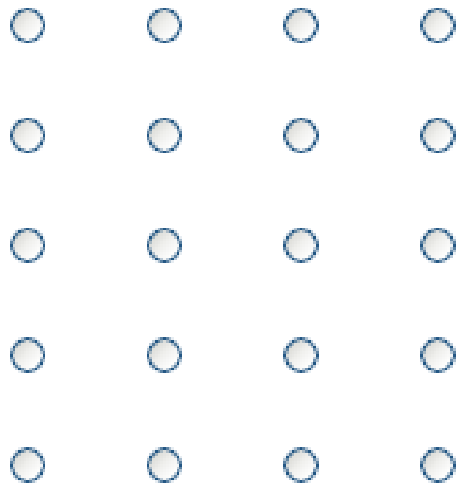


We tend to perceive any closely clustered objects as a group

Gestalt Psychology



Horizontal proximity

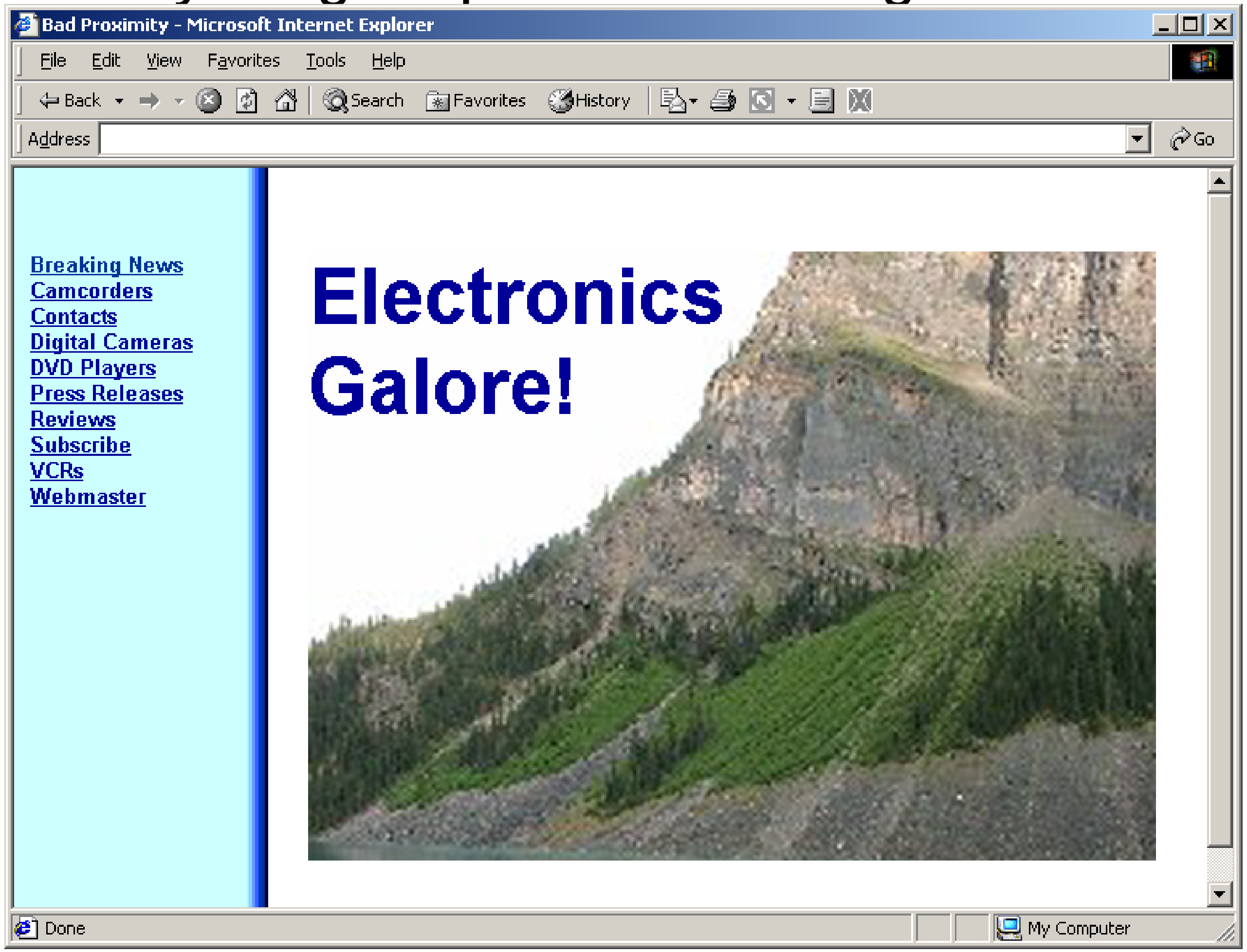


Vertical proximity

Gestalt Psychology

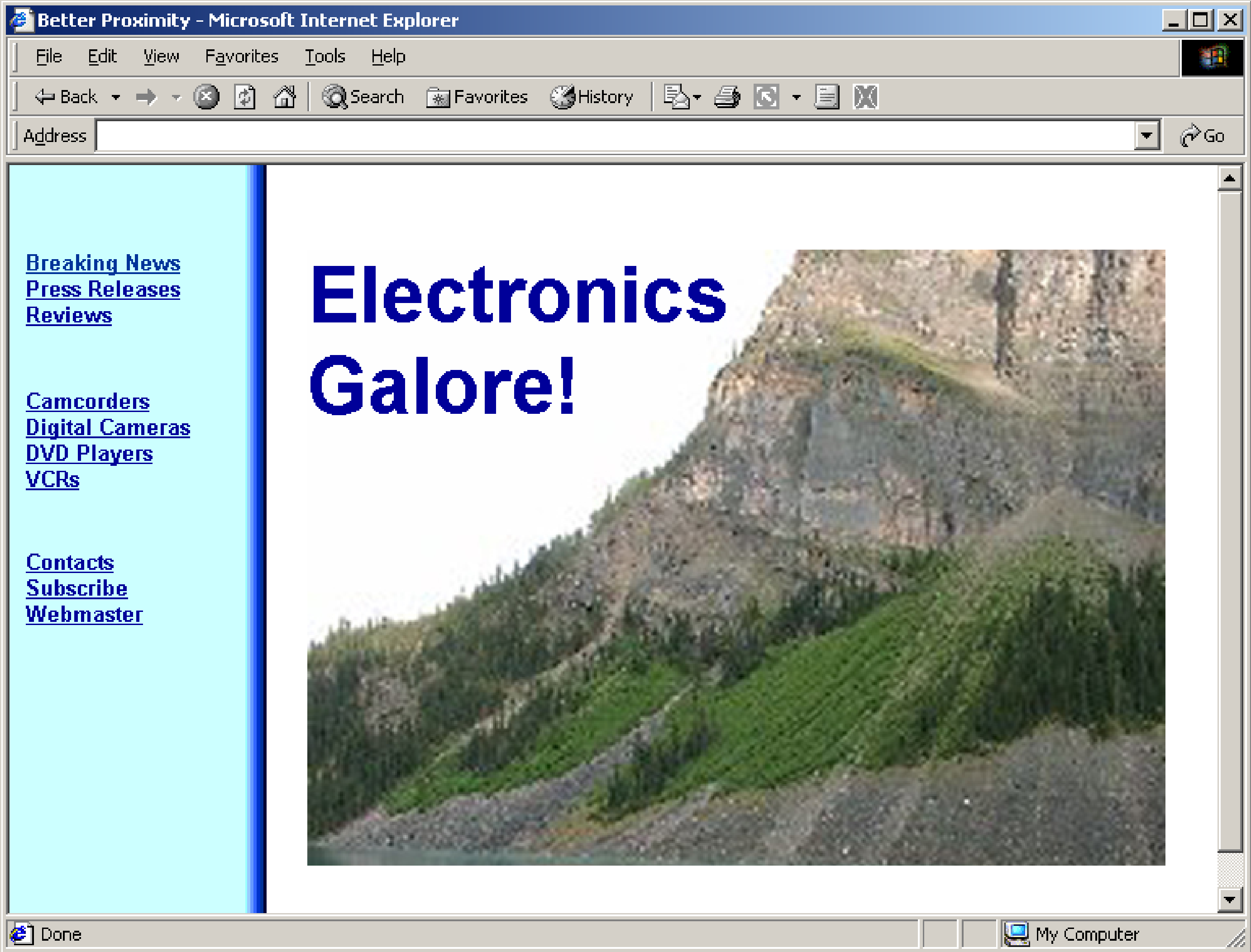
Design implication:

- Use proximity to group related things



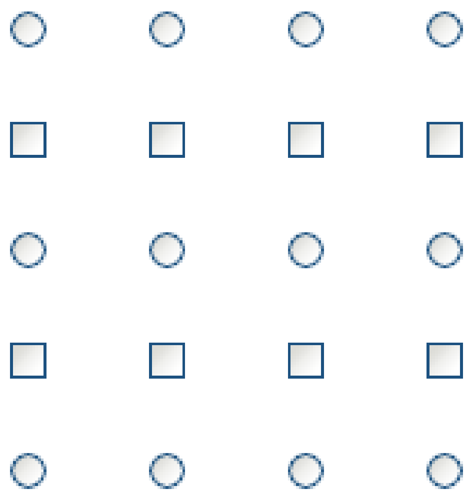
Gestalt Psychology

Improved version:

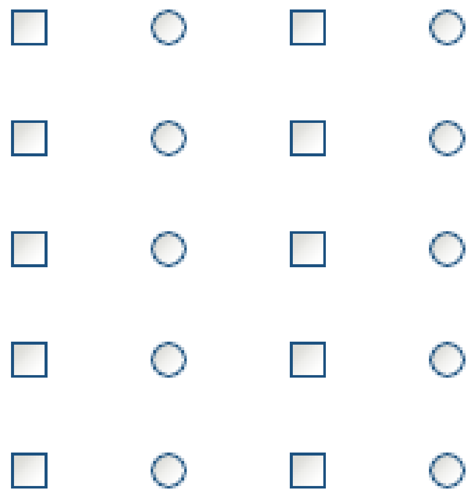


Gestalt Psychology

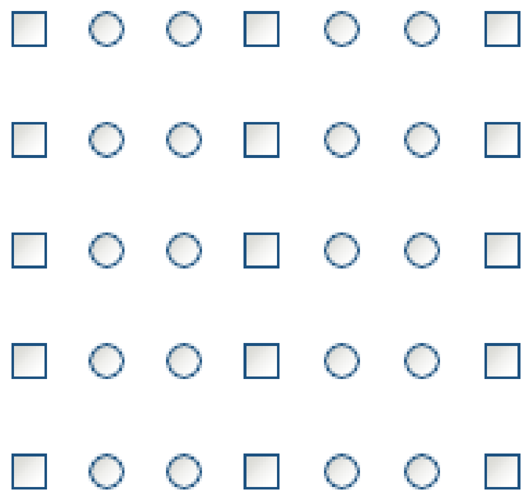
Principle of similarity: Objects that have similar visual characteristics, such as size, shape or colour will be seen as a group



Rows of similar objects



Columns of similar objects

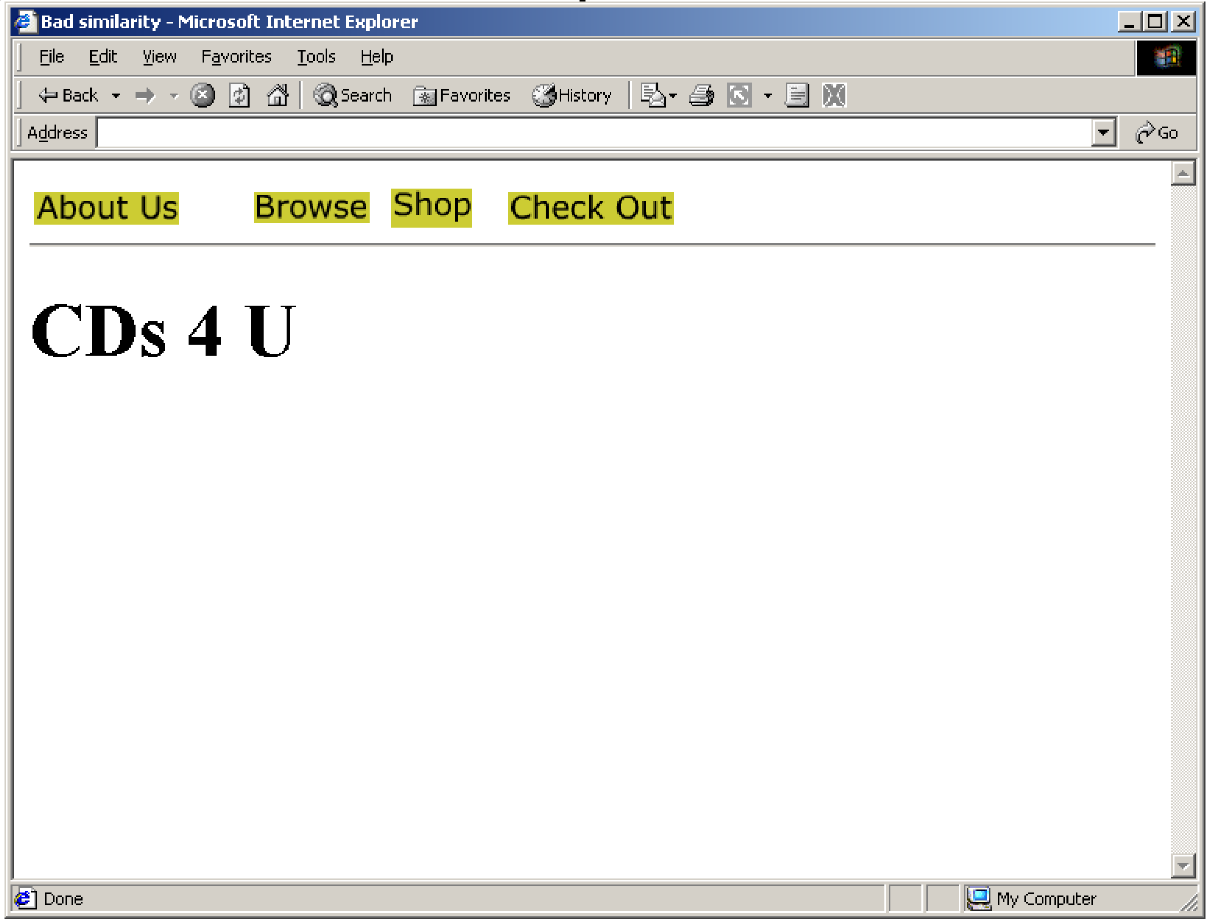


Grouped columns

Gestalt Psychology

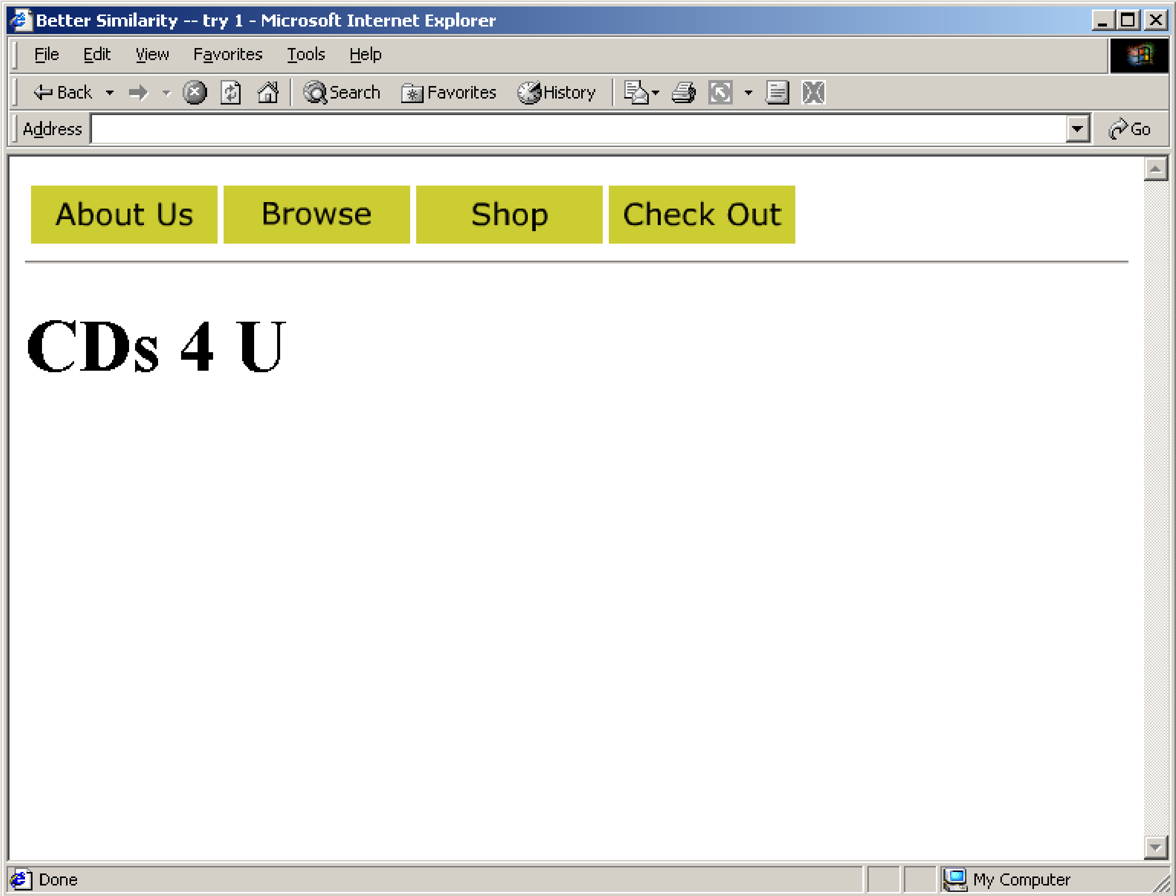
- Design implication:

Use similarity to make menu options the same size:



Gestalt Psychology

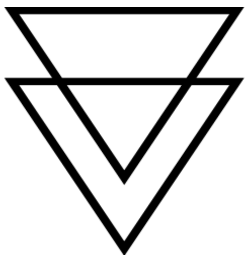
Improved version:



Apart from size, other similarity hints include shape, texture, boldness, etc.,

Gestalt Psychology

Principle of symmetry: we use our experience and expectations to make groups of things

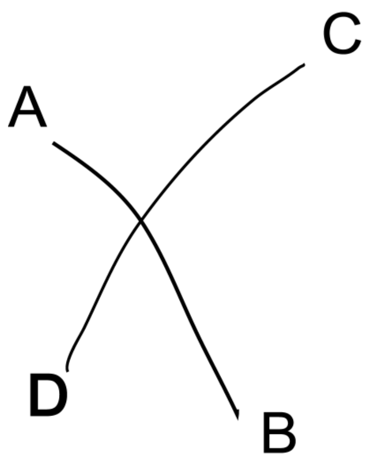


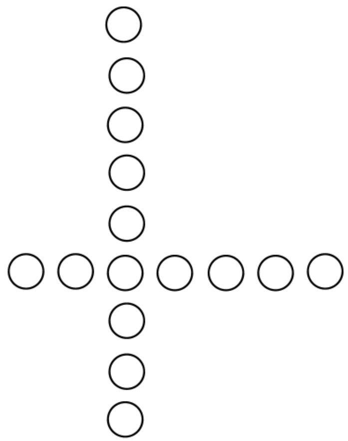
We see two triangles

We see three groups of paired square brackets

Gestalt Psychology

Principle of continuity: we group by flow of lines, that is, we tend to see things as smooth, continuous representations rather than abrupt changes



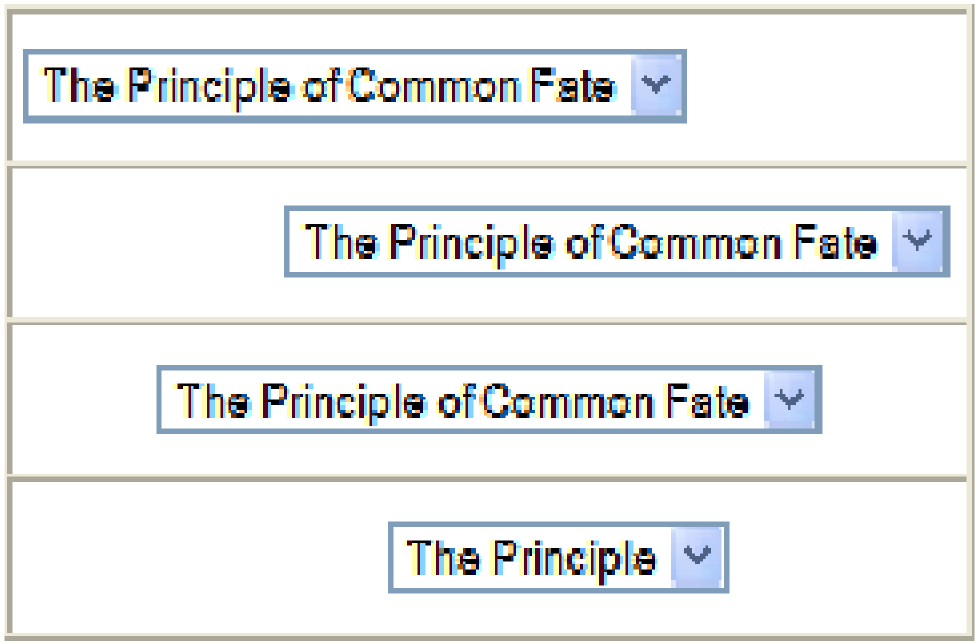


We see curves AB and CD, not AC and DB, and not AD and BC

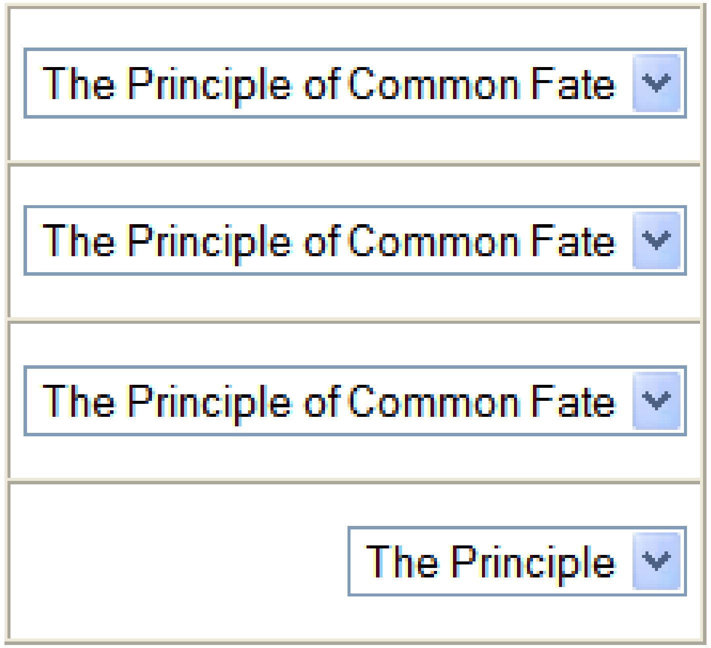
We see two rows of circles, not two L-shaped groups

Gestalt Psychology

Which is better? (a) or (b)?



(a)

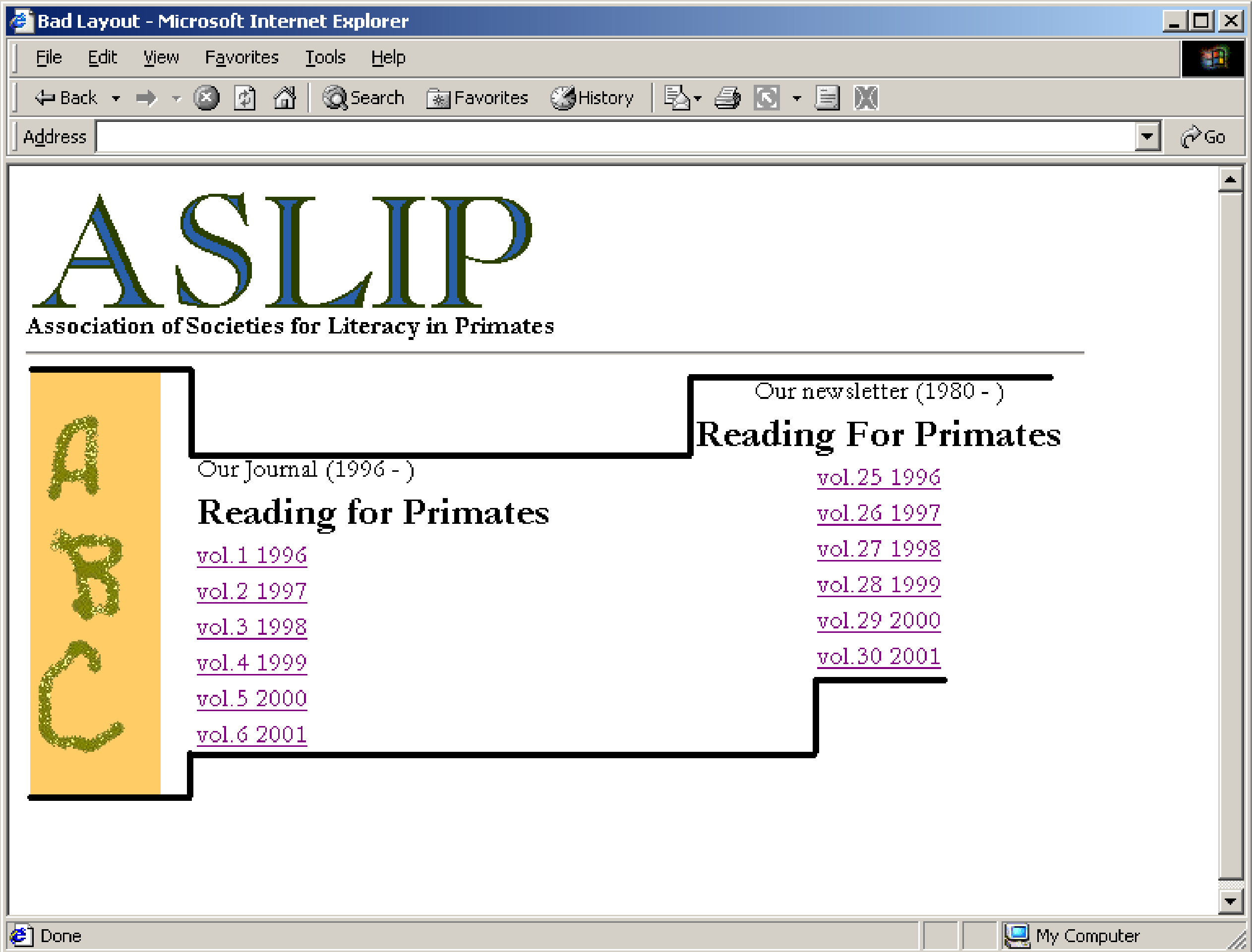


(b)

Gestalt Psychology

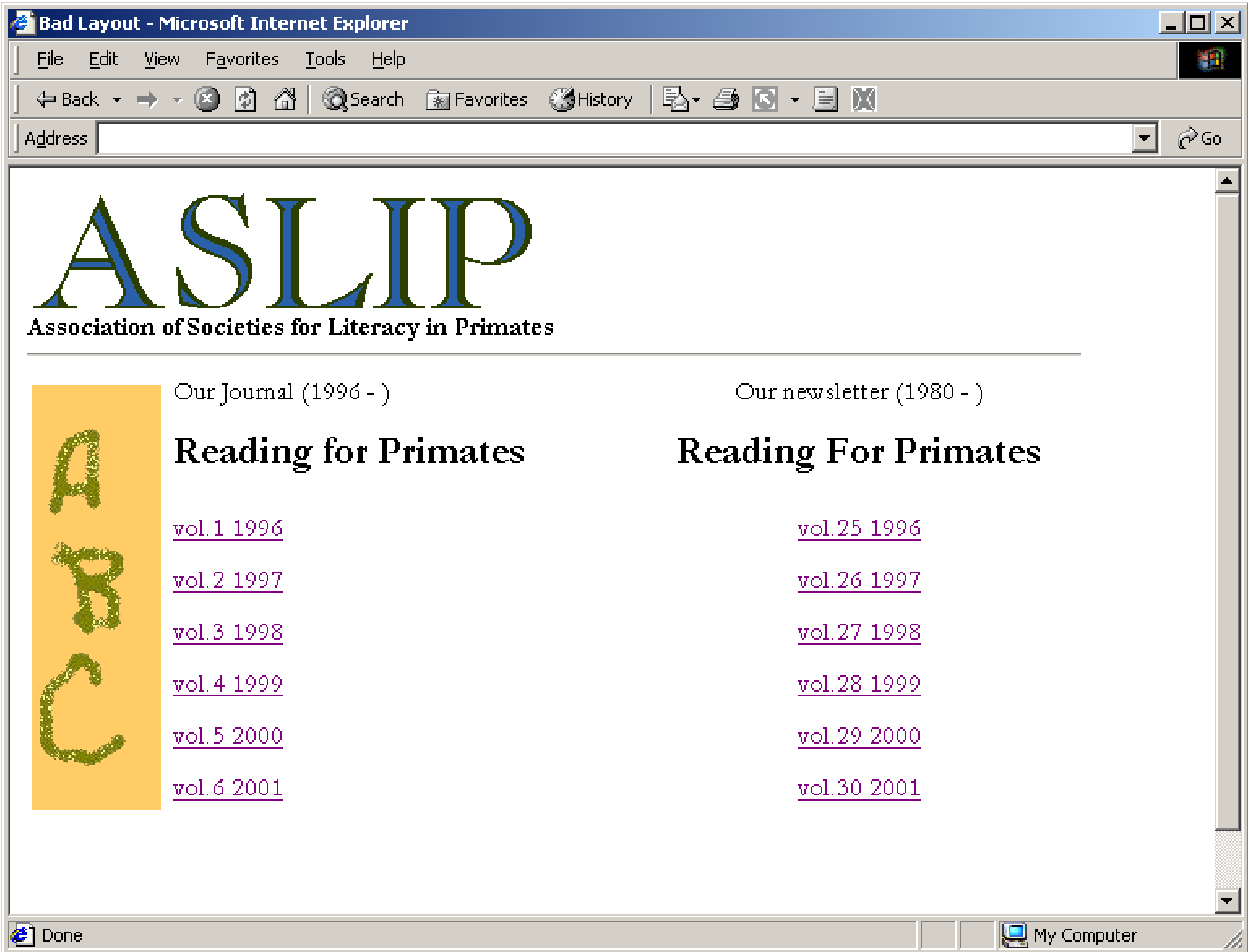
Design implication:

- Use alignment to improve layout



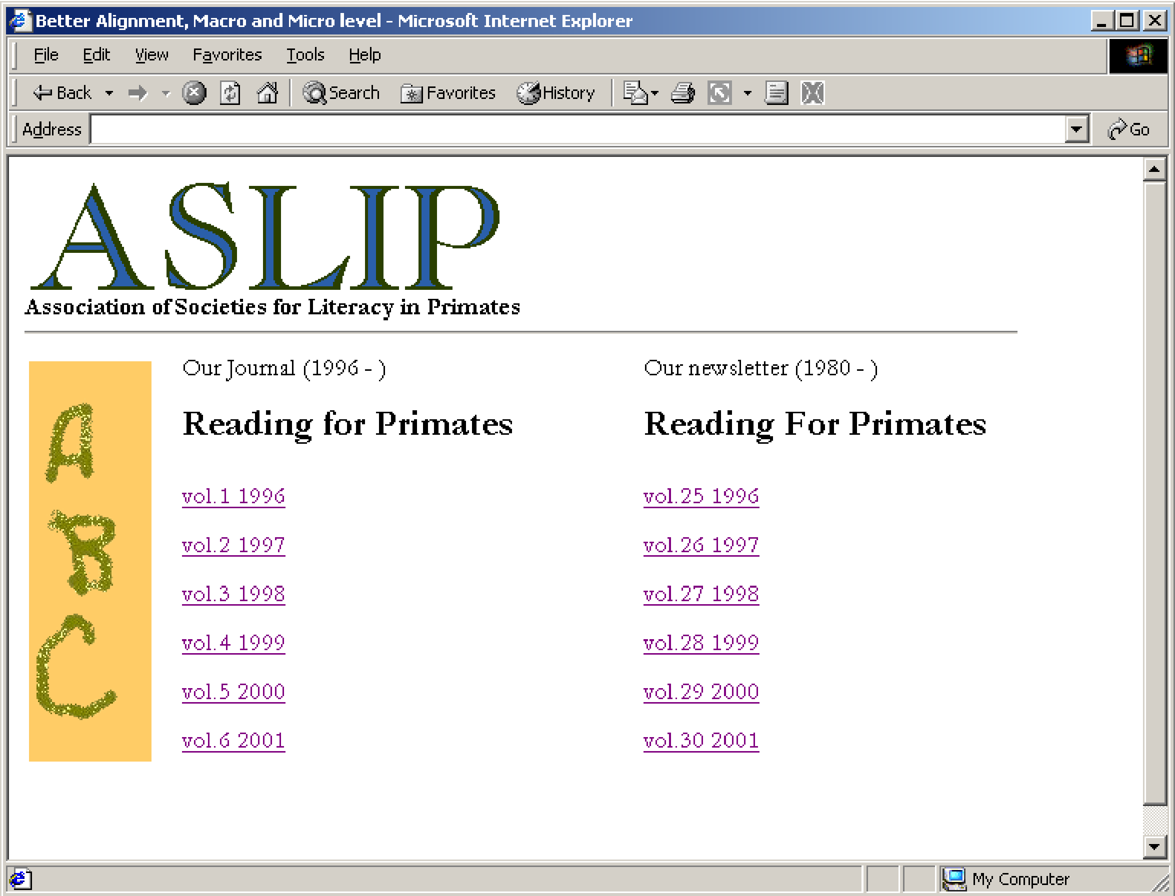
Gestalt Psychology

An improved version:



Gestalt Psychology

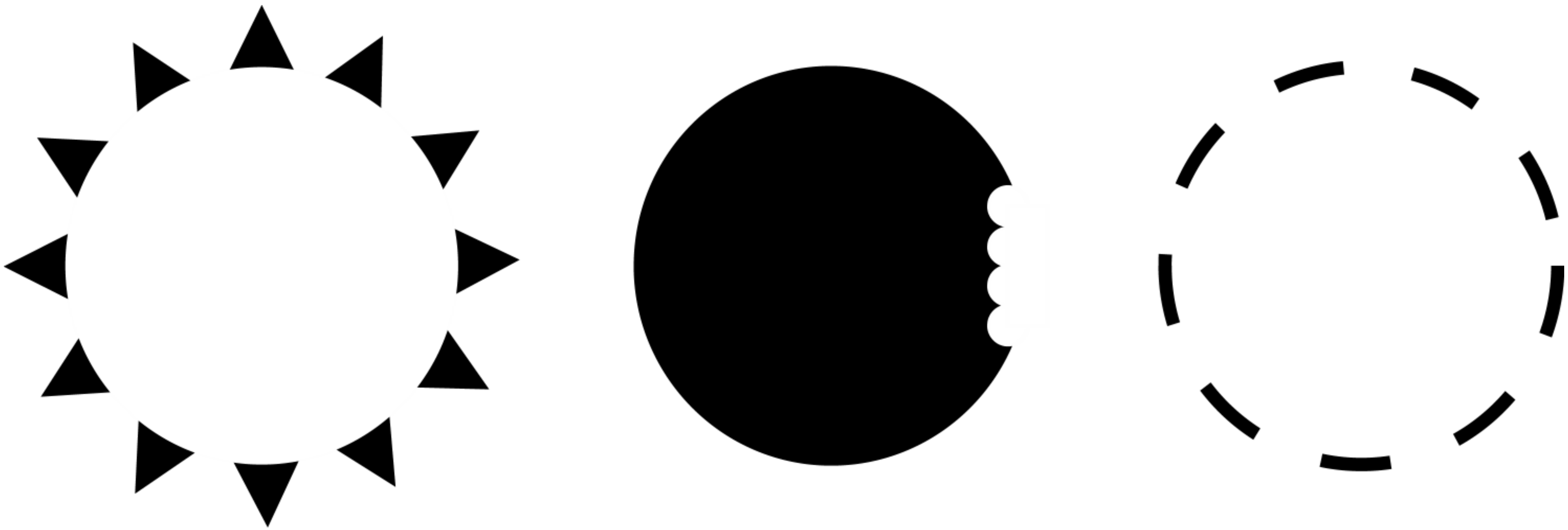
Can be further improved:



Gestalt Psychology

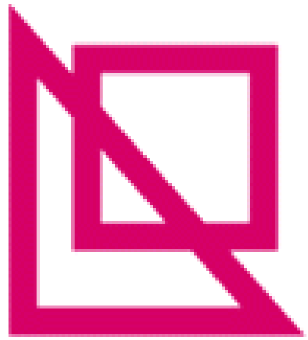
Principle of closure: we mentally “fill in the blanks”

Examples:



All are seen as circles although they are not exactly

Gestalt Psychology



Any Gestalt's principles have been applied in the above two figures?

Gestalt Psychology

Any Gestalt's principles have been applied?

Reading Speed/Accuracy

Speed of reading:

- Word shape is important to recognition

Which one is more easier to recognize?

INTRODUCTION Introduction

Counter example: it is difficult for us to detect errors, if any (Ming Pao, 2001, appeared several times with no error correction)

Reading Speed/Accuracy

- For font size, 9 to 12 points are good and similar
- For text width, 2.3 and 5.2 inches are good and similar

$$\sigma_x^2 \triangleq E\{(\hat{x}-x)^2\} = c^2 E\{(\hat{\tau}\cos(\hat{\phi}) - \tau\cos(\phi))^2\} \approx c^2 E\{(\epsilon_\tau \cos(\hat{\phi}) - \tau \sin(\phi)\sin(\epsilon_\phi))^2\} \approx c^2(\sigma_\tau^2 \cos^2(\phi) + \tau^2\sigma_\phi^2 \sin^2(\phi)) \quad (3)$$

In a similar manner, the variance of $\hat{y}$ is derived as

$$\sigma_y^2 \triangleq E\{(\hat{y}-y)^2\} \approx c^2(\sigma_\tau^2 \sin^2(\phi) + \tau^2\sigma_\phi^2 \cos^2(\phi)) \quad (4)$$

As a result, the variance of the range error, denoted by σ_r^2, is

$$\sigma_r^2 \triangleq E\{(\hat{x}-x)^2\} + E\{(\hat{y}-y)^2\} \approx c^2(\sigma_\tau^2 + \tau^2\sigma_\phi^2) \quad (5)$$

which is a function of τ, σ_τ^2 and σ_ϕ^2.

The CRLB gives a lower bound on variance attainable by any unbiased estimators and thus it can be served as a benchmark to contrast with the mean square error of the positioning algorithm. The CRLBs for x and y are computed from [7]

$$\mathrm{CRLB}(\theta_i) = [\boldsymbol{I}^{-1}(\boldsymbol{\theta})]_{i,i}, \quad i = 1,2 \quad (6)$$

where

$$[\boldsymbol{I}(\boldsymbol{\theta})]_{i,j} = -E\left\{\frac{\partial^2 \ln p(\mathbf{z}|\boldsymbol{\theta})}{\partial\theta_i \partial\theta_j}\right\}, \quad i = 1,2 \quad \text{and} \quad j = 1,2 \quad (7)$$

and

$$p(\mathbf{z}|\boldsymbol{\theta}) = \frac{1}{\sqrt{2\pi\sigma_\tau^2}} \cdot \exp\left(-\frac{1}{2\sigma_\tau^2}\left(\hat{\tau} - \frac{\sqrt{(x-x_s)^2+(y-y_s)^2}}{c}\right)^2\right) \cdot \frac{1}{\sqrt{2\pi\sigma_\phi^2}} \exp\left(-\frac{1}{2\sigma_\phi^2}\left(\hat{\phi} - \tan^{-1}\left(\frac{y-y_s}{x-x_s}\right)\right)^2\right) \quad (8)$$

is the probability density function (PDF) of $\mathbf{z} = [\hat{\tau}, \hat{\phi}]$ parameterized by the MS position, and $[\boldsymbol{I}(\boldsymbol{\theta})]_{i,j}$ represents the (i,j)th element of $\boldsymbol{I}(\boldsymbol{\theta})$, which is known as the Fisher information matrix (FIM). The FIM is computed as

$$\boldsymbol{I}(\boldsymbol{\theta}) = \frac{1}{c^2}\begin{bmatrix} \frac{\cos^2(\phi)}{\sigma_\tau^2} + \frac{\sin^2(\phi)}{\tau^2\sigma_\phi^2} & \frac{\sin(2\phi)}{2}\left(\frac{1}{\sigma_\tau^2} - \frac{1}{\tau^2\sigma_\phi^2}\right) \\ \frac{\sin(2\phi)}{2}\left(\frac{1}{\sigma_\tau^2} - \frac{1}{\tau^2\sigma_\phi^2}\right) & \frac{\sin^2(\phi)}{\sigma_\tau^2} + \frac{\cos^2(\phi)}{\tau^2\sigma_\phi^2} \end{bmatrix} \quad (9)$$

Taking the inverse of $\boldsymbol{I}(\boldsymbol{\theta})$ yields $[\boldsymbol{I}^{-1}(\boldsymbol{\theta})]_{1,1} = c^2(\sigma_\tau^2\cos^2(\phi) + \tau^2\sigma_\phi^2\sin^2(\phi))$ and $[\boldsymbol{I}^{-1}(\boldsymbol{\theta})]_{2,2} = c^2(\sigma_\tau^2\sin^2(\phi) + \tau^2\sigma_\phi^2\cos^2(\phi))$, which indicates the optimality of the TOA-AOA hybrid algorithm at sufficiently small noise conditions. As a result, the CRLB for the range is also given by $c^2(\sigma_\tau^2 + \tau^2\sigma_\phi^2)$. It is noteworthy that (2) is in fact the maximum likelihood estimate because (8) is maximized at $(\hat{x}, \hat{y})$.

3. Simulation Results

Extensive computer simulations were conducted to evaluate the TOA-AOA hybrid mobile positioning algorithm using a single BS with multiple antennas in the LOS scenario. It was assumed that necessary changes to the mobile networks had been made [4] so that the measured TOA and AOA were of high accuracy, even in the presence of multipath propagation [8]. We considered a microcell with radius of 500 m and the measurement errors were uncorrelated zero-mean Gaussian processes. The worst-case performance was investigated such that the MS was randomly located at the cell boundary with ϕ uniformly distributed over $[0, 2\pi)$.

Figure 1 shows the standard deviation of the range error for $\sigma_\tau \in [-80, -50]$ dBs at $\sigma_\phi = 0$ and $\sigma_\phi = 0.1$ rad. It can be seen that the estimation accuracy of the hybrid estimator met the CRLBs for the range in both cases. Note that at $\sigma_\phi = 0.1$ rad, the range deviation was approximately equal to 17 dBm or $\sigma_r \approx 50$ m, for $\sigma_\tau < -68$ dBs because the AOA error dominated. Another similar test to examine the location error versus σ_ϕ at $\sigma_\tau = 0$ and $\sigma_\tau = 0.1\,\mu$s was also performed and the results are shown in Fig. 2. Again, the range deviations agreed well with the CRLBs except that there was slight discrepancy for $\sigma_\phi > -3$ dBrad because (3) and (4) were derived based on small ϵ_ϕ assumption. For

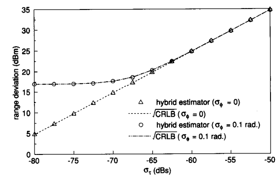


Fig. 1 Range standard deviation versus σ_τ.

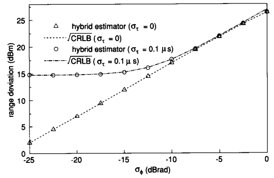


Fig. 2 Range standard deviation versus σ_ϕ.

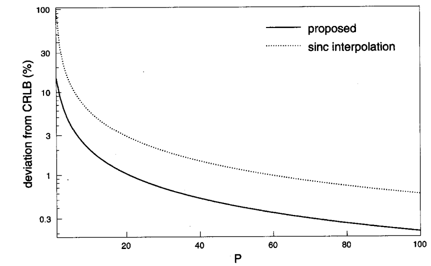


Fig. 1. Deviation from CRLB versus P for white signal.

limiting value $\lim_{P\to\infty}\sum_{j=-P}^{P}\mathrm{sinc}'^2(j-D) = \pi^2/3$ even for a small P, and it can be shown that (10) is an unbiased estimator for white $s(k)$, the mean square delay error (MSDE) of the proposed method will approach the CRLB for a wide range of filter lengths. On the other hand, the delay variance using sinc interpolation is given by

$$\mathrm{var}(\hat{D}^o) \approx \mathrm{CRLB}\frac{3\sum_{j=-P}^{P}\mathrm{sinc}'^2(j-D)}{\pi^2(\sum_{j=-P}^{P}\mathrm{sinc}(j-D)\,\mathrm{sinc}''(j-D))^2}, \quad (16)$$

where it also attains the CRLB as $P\to\infty$ but has a convergence rate lower than (15). To illustrate this, Fig. 1 plots the deviation from the CRLB, that is, $(\mathrm{var}(\hat{D}^o) - \mathrm{CRLB})/\mathrm{CRLB}$, for both schemes versus P at $D = 0.7$ s, and it can be observed that the percentage error of (15) is less than that of (16) for the whole range of P by approximately 3–6 times. It is noteworthy that since the sinc interpolator is biased for finite P, the resultant MSDE will be much larger than (16).

4. Numerical examples

Simulation tests were carried out to evaluate the performance of the proposed delay estimator using least-squares filter weights. Comparisons of MSDEs were also made with the sinc interpolator and the CRLB. The searching procedures of (2) and (10) were performed by the bisection method. The source signal was Gaussian distributed with unity power and different SNRs were obtained by proper scaling of the random noise sequences. For simplicity, the additive noises were assigned to have identical power. The time difference D was set to 0.7 s, the data length N was 1000 and $\alpha = 1$ was selected. The MSDEs obtained were based on 1000 independent runs.

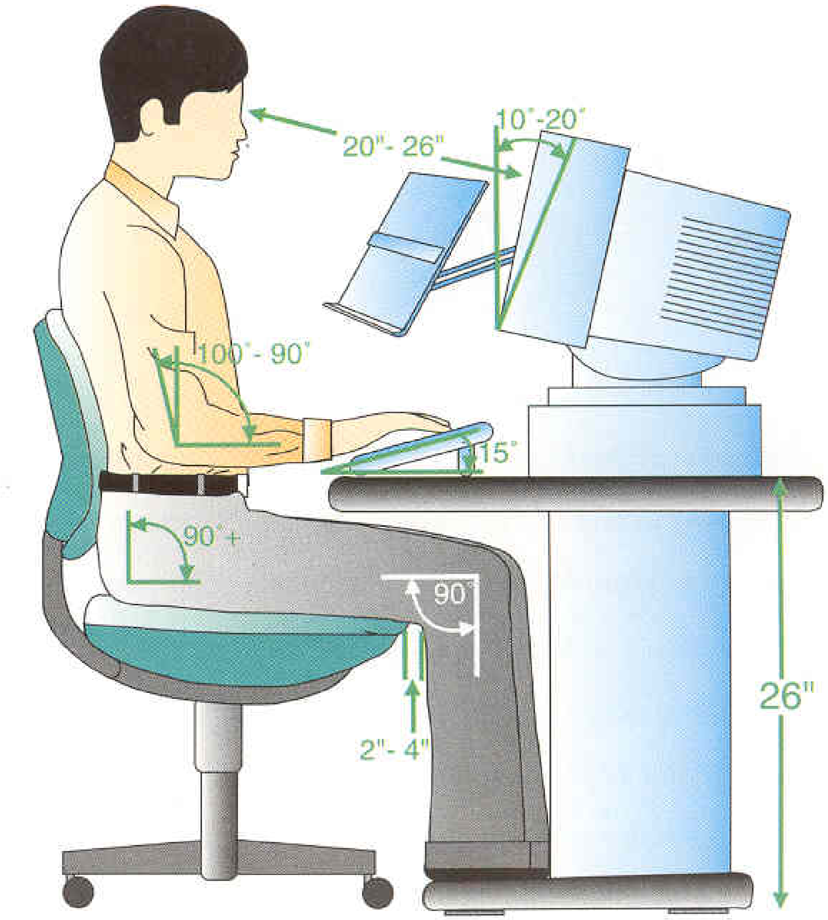
In the first test, the source signal was a white process. Fig. 2 shows the MSDEs of the proposed method and sinc interpolator using $P = 3$ and $P = 15$, as well the CRLB, for SNR $\in [-10, 20]$ dB. It can be seen that when SNR $\geqslant -6$ dB, the proposed approach was superior to the sinc interpolation method using $P = 3$ and $P = 15$, for the whole range of SNRs and for SNR $\geqslant 4$ dB, respectively. Furthermore, the proposed method with $P = 3$ and $P = 15$ had very similar performance and both met the CRLB for SNR $\geqslant -6$ dB, which indicated that the delay estimation performance of (10) was almost

Hearing

- Human can hear frequencies from 20Hz to 15kHz
- Less accurate in distinguishing high frequencies than low frequencies
- Auditory system filters sounds - can attend to sounds over background noise/interference. For example, we can talk with our friend in a very noisy Chinese restaurant (Cocktail party phenomenon)
- Apart from hearing sound, our ears are capable to get the distances and directions of the sound sources

Touch

- Key sense for visually impaired persons
- Aspects include



Touch

- Productivity can be affected by our position as well as our feeling of the contacting equipment, e.g., a chair
- From http://www.lamex.com.hk :

"A healthy office chair, one that is ergonomically designed can do so much for the user as well as for the company. An employee who is healthy takes less time off work and while at work is more productive..."

Movement

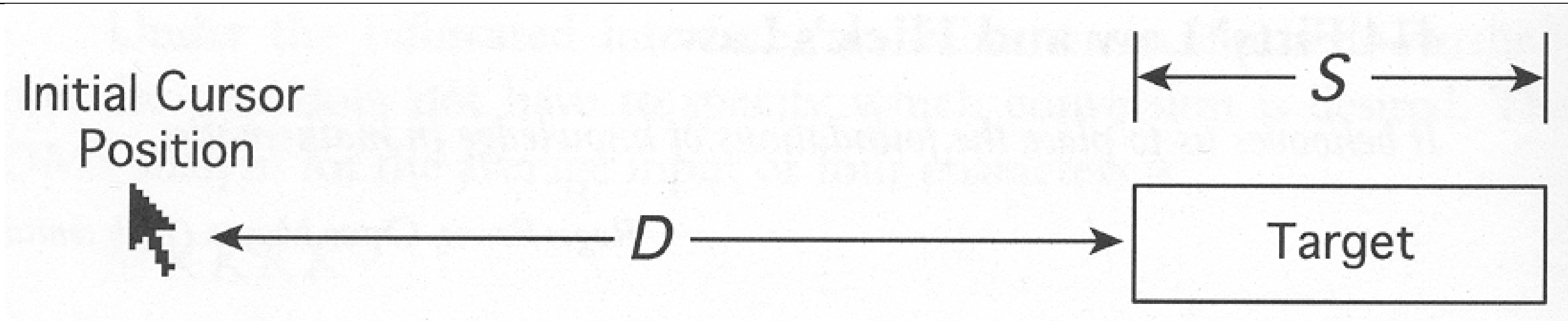
- Time taken to respond to stimulus: reaction time + movement time

- Reaction time - depend on stimulus type
  - Visual - 200ms
  - Auditory - 150ms
  - Pain - 700ms
  - Combined signal will result in faster response

- Movement time - dependent on age, fitness, etc.

- ↓ reaction time ↓ accuracy in unskilled operator but not in skilled operator

Movement



Fitts' law describes the average time taken to hit a screen target:

$$T_M = a + b \log_2(D/S + 1)$$

where

- a & b are constants determined experimentally
- T_M is movement time (in ms)
- D is Distance
- S is Size

$\Rightarrow$ Targets in general should be large as possible & the distances as small as possible

Movement

Example:

- Suppose for a 15-inch flat panel display, the average distance the cursor between the menu bars is 80 mm
- Size of menu bar - Macintosh: 50 mm & Windows: 5mm
- a=50, b=150

Calculated time to move the cursor to a menu item on Macintosh

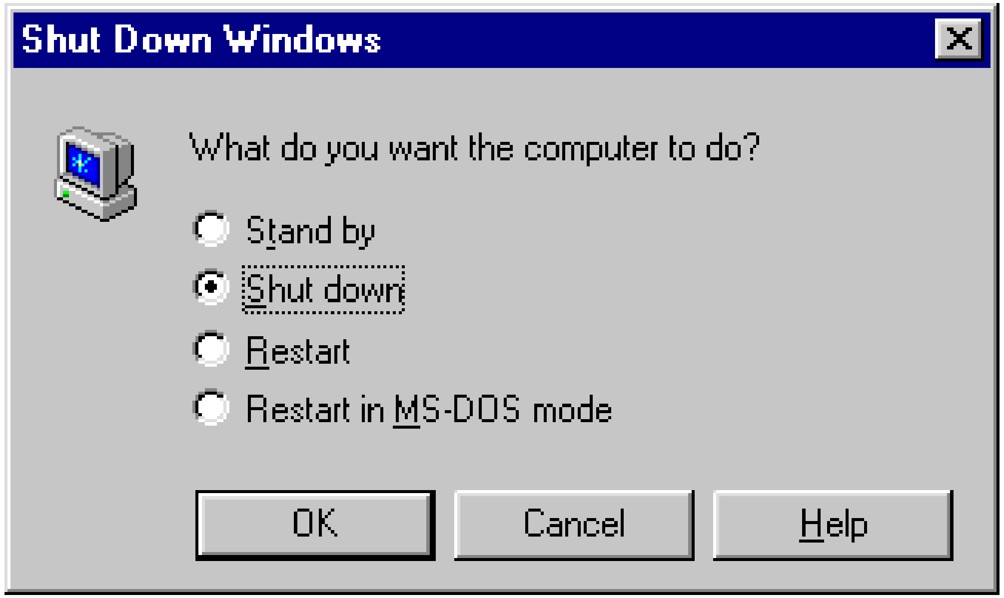
$T_M = 50 + 150 \log_2(80/50 + 1) = 256$ ms

For Windows,

$T_M = 50 + 150 \log_2(80/5 + 1) = 663$ ms

Movement

When there are multiplicity of choices, we need to choose the appropriate target prior to moving the cursor:



Required time to choose can be described by Hick's law:

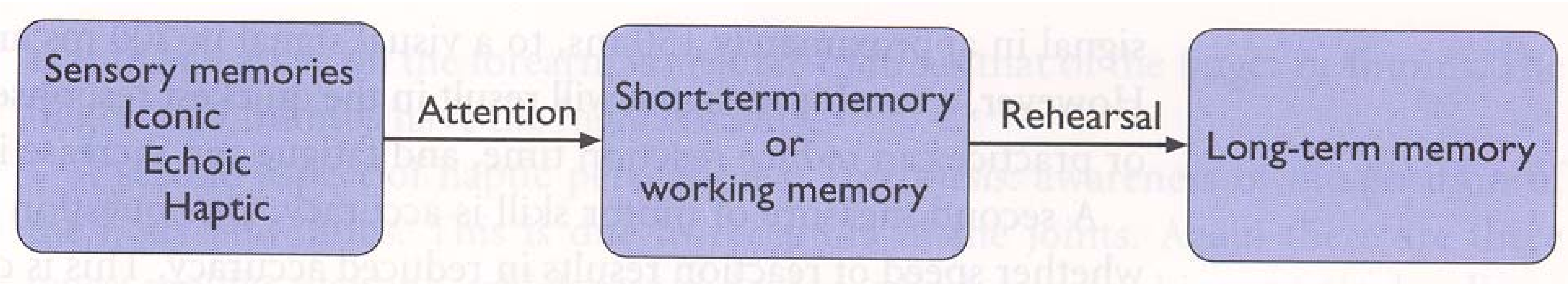
$$T_C = a + b \log_2(N+1)$$

where N is number of options and the probabilities of taking each alternative are equal

Memory

3 types of memory model

- Sensory memory (vs I/O buffer)
  - Hold data received from external world
- Short-term or working memory (vs RAM)
  - Where information is processed
- Long-term memory (vs hard disk)
  - Hold information for long time, although not all information can be retrieved evenly



Memory

- Sensory memory acts as buffers for stimuli received via senses
- Constantly overwritten
- Information passes from sensory to short-term memory by attention (e.g., you are constantly seeing but you will not pay attention to all things you see)
- Attention or selection of stimuli is governed by level of interest or need

  e.g., cocktail party phenomenon: we can attend to one conversation over background noise but we may choose to switch our attention to another conversation if we hear our name mentioned

Memory

- Short-term memory (STM) is used for temporary recall of information
  - Rapid access - 70ms
  - Rapid decay - 200ms
  - Limited capacity - 7 +/- 2 digits or chunks

- Long-term memory (LTM) is the main resource for all our knowledge
  - Slow access - 100 ms
  - Slow decay, if any
  - Huge or unlimited capacity

Memory

Memory capacity can be improved via:

- Chunking
- Let people recognize information rather than recall it

How many chunks in the following?

85227887780

The chunks can be 852, 2, 7, 8, 8, 7, 7, 8, 0 $\Rightarrow$ 9 chunks

How about this?

852 2788 7780

There are now 3 chunks: 852, 2788, 7780

However, sometimes we cannot do chunking, e.g., can you remember:

vsdfnjejn7dknsdnd33s

Memory

Design implication:

- Facilitate users to do chunking, e.g., make your URL easy for chunking:

www.bestbookbuys.com

The chunks are:

www.
best
book
buys
.com

Another application is to use chunking in memorizing phone number, 2788, 7780 (although 27, 887, 780 is possible)

Memory

Recognition versus Recall:

Is my telephone number 2788 7780?
What is my telephone number?

Which one does not belong to Norman's usability principles?

A. Affordance
B. Constraints
C. Flexibility
D. Feedback
E. None of the above

State Norman's usability principles.

- Multiple choice: you can recognize the answer
- Essay: you must recall the answer

Memory

Design implication:

- Design systems that rely on people's ability to recognize information rather than forcing them to recall it, in order to reducing user's memory burden

  e.g., a computer with a GUI allows us to recognize commands on a menu, instead of remembering them as in DOS and UNIX

Reasoning

- Three forms of reasoning:

1. Deductive reasoning

   - Derive logically necessary conclusion from given premises
     e.g., If it is Friday then she will go to work
     $\Rightarrow$ It is Friday. Therefore she will go to work
   - Logical conclusion not necessarily true:
     e.g., If it is raining then the ground is dry
     $\Rightarrow$ It is raining. Therefore the ground is dry
     $\Rightarrow$ It is valid deduction but not true
   - Human deduction poor when truth & validity clash

Reasoning

2. Inductive reasoning

- Generalise from cases seen to cases unseen
  e.g., All elephants we have seen have trunks therefore all elephants have trunks.
- Unreliable: can only prove false not true.
- However, humans are not good at using negative evidence e.g., Wason's cards

Reasoning

Wason's cards: each card has a number on one side and a letter on the other

Statement "if a card has a vowel on one side it has an even number on the other side"

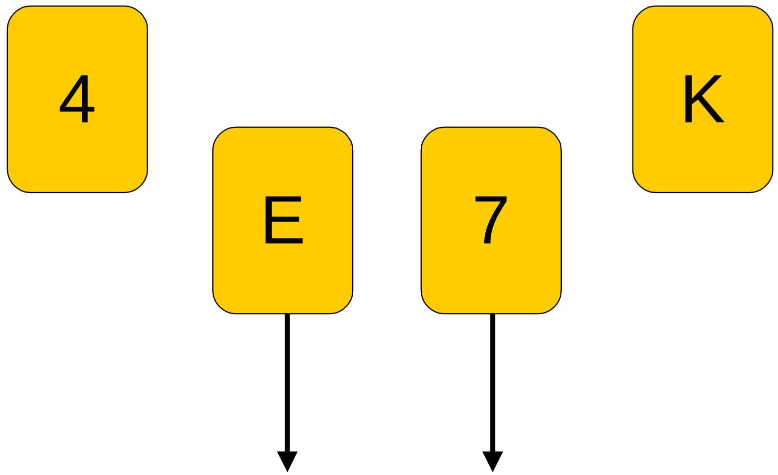
4	E	7	K

Which card(s) would you need to pick up to check this statement?

Reasoning

Most people: E & 4

In fact, we need to check E & 7



$\because$“If A, then B.”

$\Leftrightarrow$ “If NOT B then NOT A.”

(a) E (to check if A then B)
(b) 7 (to check if NOT B then NOT A)
(c) 4 (to check if B then what)
(d) K (to check if NOT A then what)

(c) & (d) are no use for checking the statement.

Reasoning

How about if the condition "each card has a number on one side and a letter on the other" is not stated? Which card(s) would you need to pick up to check the statement?

Design implication:

Avoid negative evidence, e.g., If not Exit, don't press "X"

3. Abductive reasoning

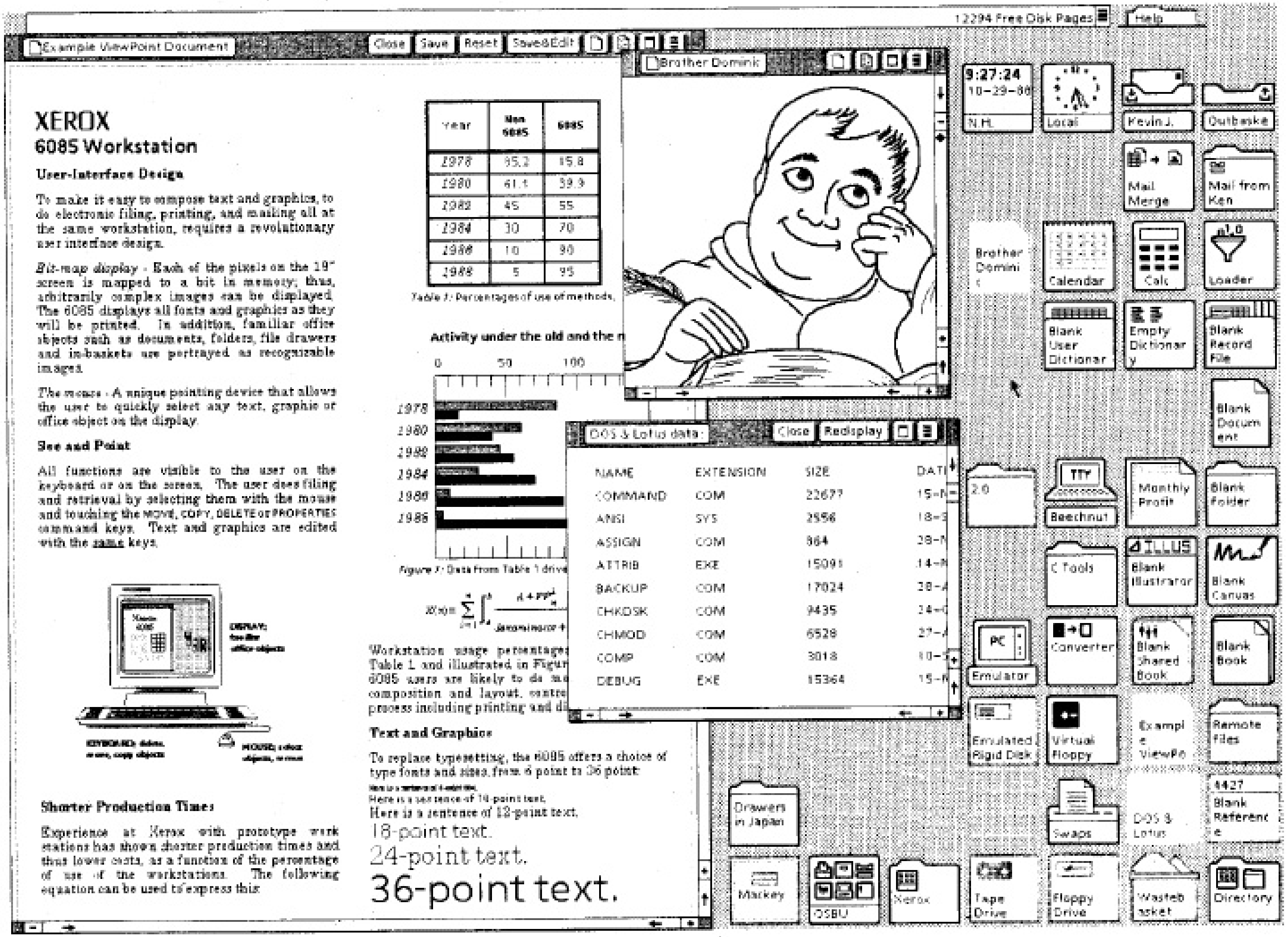
- Reasoning from event to cause
  e.g., Sam drives fast when drunk
  If see Sam driving fast, assume drunk
- Unreliable: can lead to false explanations.
  e.g., Sam may need to do an emergency matter

Conceptual Model

- It is a high-level description of how a system is organized and operates
- It outlines what people can do with a product and what concepts are needed to understand how to interact with it
- If the conceptual model meets the user's intention, this implies that the user will use the system easily.
- How to develop a conceptual model?
  - Identify user's needs and system requirements
  - Identify a set of possible ways of interactions
  - Select suitable metaphors and analogies

Conceptual Model

A classic example is the Star interface by Xerox



Conceptual Model

- Targeted for workers not interested in computing – make the computer as “invisible” to the users as possible and to design applications suitable to them
- Based on an analogy to a physical office
- Metaphors: paper, folders, filing cabinets and mailboxes were represented as icons on the screen and were designed to possess some of their properties of their physical counterparts
- Concepts: Dragging an electronic document onto an electronic folder was seen as being analogous to placing a physical document into a physical cabinet; Placing an electronic file onto the printer icon would print it out

Conceptual Model

- Consider a company that wants to develop a wireless information system to help tourists with personal digital assistants (PDAs) in Hong Kong.

  How to develop a conceptual model for this system?

  What questions should we ask in developing the conceptual model?

Conceptual Model

Suggestions:

- Who are they? Chinese or English speaking foreigners?
- What do tourists want? Information.
- How to get from airport to downtown?
- Where is a good Chinese restaurant?
- How to support the activity of requesting information in the optimum way? A menu system or voice command activated system? Provide a system that structures information in the form of lists, maps, recommendations, etc.?
- Concepts??

Mental Model

- Don Norman's definition: "the model people have of themselves, others, the environment, & the things with which they interact. People form mental models through experience, training & instruction"
- An internal representation of a user's current conceptualization and understanding of a system
- Knowledge developed in learning & using a system – How to use it? How it works?

  e.g., Make a phone call:
  Pick up the phone
  Dial the number I want to call
  Hear the phone on the other end ringing
  The person at the other end answers

Mental Model

- Mental models are:
  - Unscientific—They are often based on guesswork and approximations
  - Partial—They do not necessarily describe whole systems, just the aspects that are relevant to the persons who formulate them
  - Unstable—They are not concrete formulations, but evolve and adapt to the context
  - Inconsistent—They do not necessarily form a cohesive whole; some parts may be incompatible with other parts of the same model
  - Personal—They are specific to each individual and are not universal concepts that can be applied generally

Mental Model

- Help to predict the operation of an unknown/unfamilar system

  e.g., in an unfamiliar flat, we guess the light should be turned on using the nearest switch

- Users always have mental models & always develop & modify them, regardless of the particular design of a system

- By studying how people create mental models of interactive systems and by designing interactive systems that help the user create a more accurate mental model of the system, usability will improve.

- Successful interface is built when

  our conceptual model agrees with user's mental model