The Human

Overview

Human can be viewed as an information processing system, for example, Card, Moran and Newell's Model Human Processor.

A simple model:

- information received and responses given via input–output channels
- information stored in memory
- information processed and applied in various ways

Capabilities of humans in these areas are important to design, as are individual differences.

Input–Output channels

Vision

Two stages in vision

- physical reception of stimulus
- processing and interpretation of stimulus

The physical apparatus: the eye

- mechanism for receiving light and transforming it into electrical energy
- light reflects from objects; their images are focused upside-down on retina
- retina contains rods for low light vision and cones for colour vision
- ganglion cells detect pattern and movement

Interpreting the signal

Size and depth

- visual angle indicates how much of field of view object occupies (relates to size and distance from eye)
- visual acuity is ability to perceive fine detail (limited)
- familiar objects perceived as constant size in spite of changes in visual angle — law of size constancy
- cues like overlapping help perception of size and depth

Interpreting the signal (cont)

Brightness

- subjective reaction to levels of light
- affected by luminance of object
- measured by just noticeable difference
- visual acuity increases with luminance as does flicker

Colour

- made up of hue, intensity, saturation
- cones sensitive to colour wavelengths
- blue acuity is lowest
- 8% males and 1% females colour blind

Interpreting the signal (cont)

The visual system compensates for movement and changes in luminance.

Context is used to resolve ambiguity.

Optical illusions sometimes occur due to over compensation.

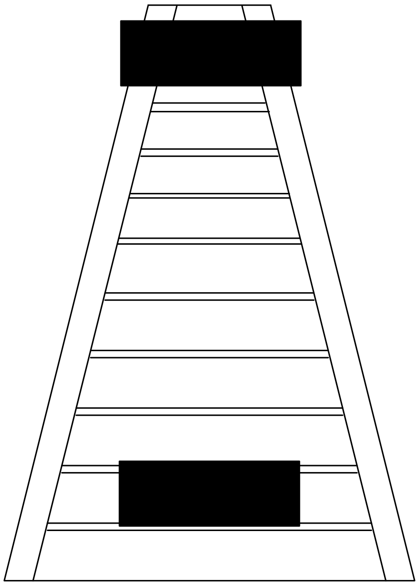


Figure 1: The Ponzo illusion

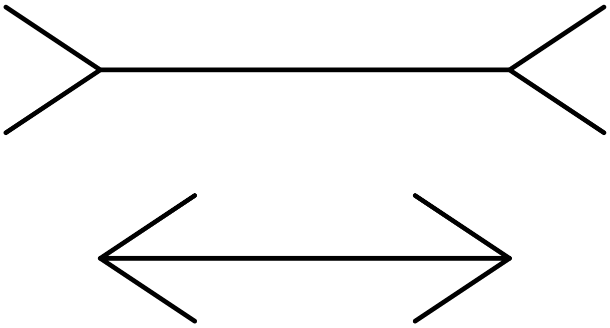


Figure 2: The Muller Lyer illusion

Reading

Several stages:

- visual pattern perceived
- decoded using internal representation of language
- interpreted using knowledge of syntax, semantics, pragmatics

Reading involves saccades and fixations. Perception occurs during latter.

Word shape is important to recognition.

Negative contrast improves reading from computer screen.

Hearing

Provides information about environment: distances, directions, objects etc.

Physical apparatus:

- outer ear — protects inner and amplifies sound
- middle ear — transmits sound waves as vibrations to inner ear
- inner ear — chemical transmitters are released and cause impulses in auditory nerve

Sound

- pitch — sound frequency
- loudness — amplitude
- timbre — type or quality

Hearing (cont)

Humans can hear frequencies from 20Hz to 15kHz — less accurate distinguishing high frequencies than low.

Auditory system filters sounds — can attend to sounds over background noise. For example, the cocktail party phenomenon.

Touch

Provides important feedback about environment.

May be key sense for someone who is visually impaired.

Stimulus received via receptors in the skin:

- thermoreceptors — heat and cold
- nociceptors — pain
- mechanoreceptors — pressure (some instant, some continuous)

Some areas more sensitive than others e.g. fingers.

Kinethesis — awareness of body position affecting comfort and performance.

Movement

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

Movement time — dependent on age, fitness etc.

Reaction time — dependent on stimulus type:

- visual — 200ms
- auditory — 150 ms
- pain — 700ms

Increasing reaction time decreases accuracy in the unskilled operator but not in the skilled operator.

Movement (cont)

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

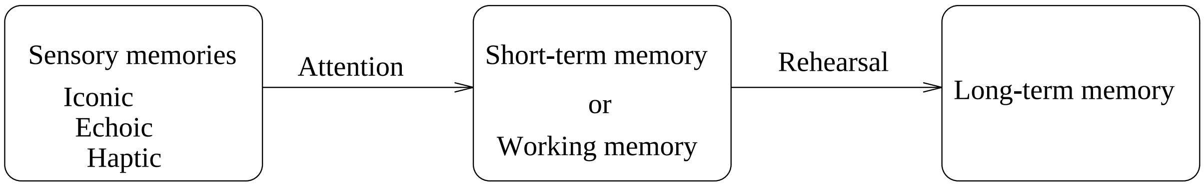
$$Mt = a + b\, log_2(D/S + 1)$$

where a and b are empirically determined constants, Mt is movement time, D is Distance and S is Size.

Targets in general should be large as possible and the distances as small as possible.

Memory

There are three types of memory function.



Sensory memory

Buffers for stimuli

- iconic — visual stimuli
- echoic — aural stimuli
- haptic — touch stimuli

Constantly overwritten.

Information passes from sensory to STM by attention.

Selection of stimuli governed by level of arousal.

Short-term memory (STM)

Scratch-pad for temporary recall

- rapid access — 70ms
- rapid decay — 200ms
- limited capacity — $7 + / - 2$ digits or chunks of information

Recency effect — recall of most recently seen things better than recall of earlier items.

Some evidence for several elements of STM — articulatory channel, visual channel etc. — interference on different channel does not impair recall.

Long-term memory (LTM)

Repository for all our knowledge

- slow access — 1/10 second
- slow decay, if any
- huge or unlimited capacity

Two types

- episodic — serial memory of events
- semantic — structured memory of facts, concepts, skills

Information in semantic LTM derived from episodic LTM.

Long-term memory (cont.)

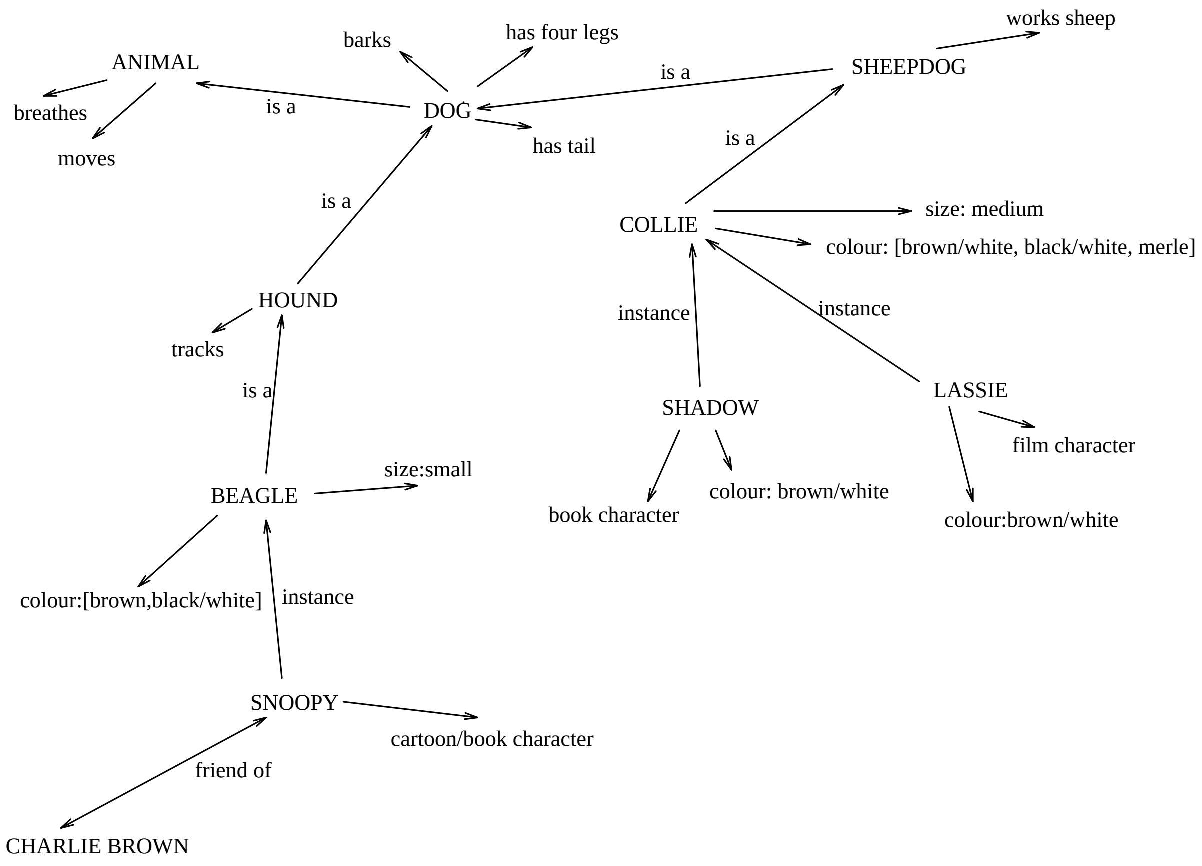
Semantic memory structure

- provides access to information
- represents relationships between bits of information
- supports inference

Model: semantic network

- inheritance — child nodes inherit properties of parent nodes
- relationships between bits of information explicit
- supports inference through inheritance

Long-term memory (cont.)



Long-term memory (cont.)

Other models of LTM

Frames:

> Information organized in data structure. Slots in structure are instantiated with particular values for a given instance of data.

DOG

Fixed
- legs: 4

Default
- diet: carnivorous
- sound: bark

Variable
- size:
- colour:

COLLIE

Fixed
- breed of: DOG
- type: sheepdog

Default
- size: 65 cm

Variable
- colour:

Long-term memory (cont.)

Scripts:

> Model of stereotypical information required to interpret situation or language. Script also has elements which can be instantiated with particular values.

Script for a visit to the vet

Entry conditions:	*dog ill* *vet open* *owner has money*	Roles:	*vet examines* *diagnoses* *treats* *owner brings dog in* *pays* *takes dog out*
Result:	*dog better* *owner poorer* *vet richer*	Scenes:	*arriving at reception* *waiting in room* *examination* *paying*
Props:	*examination table* *medicine* *instruments*	Tracks:	*dog needs medicine* *dog needs operation*

Long-term memory (cont.)

Production rules:

> Representation of procedural knowledge. Condition–action rules — if condition is matched, rule fires.

LTM processes

Storage of information

- information moves from STM to LTM by rehearsal
- amount retained proportional to rehearsal time: total time hypothesis
- optimized by spreading learning over time: distribution of practice effect
- structure, meaning and familiarity make information easier to remember

LTM processes (cont.)

Forgetting

- decay – information is lost gradually but very slowly
- interference — new information replaces old: retroactive interference
- old may interfere with new: proactive inhibition — so may not forget at all
- memory is selective and affected by emotion — can 'choose' to forget

Information retrieval

- recall — information reproduced from memory. Can be assisted by cues, e.g. categories, imagery
- recognition — information gives knowledge that it has been seen before. Less complex than recall — information is cue.

Thinking: reasoning and problem solving

Reasoning

Deductive: derive logically necessary conclusion from given premises. E.g.

> If it is Friday then she will go to work
> It is Friday
> Therefore she will go to work.

Logical conclusion not necessarily true:

> If it is raining then the ground is dry
> It is raining
> Therefore the ground is dry

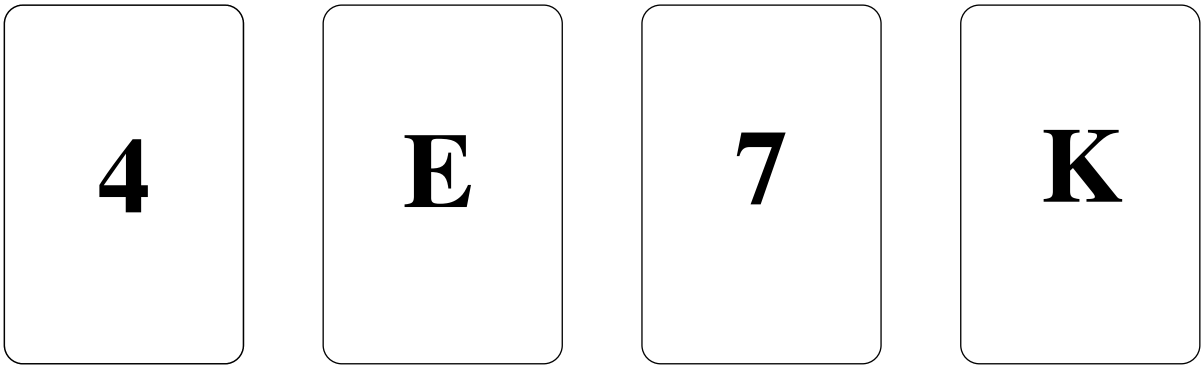
Human deduction poor when truth and validity clash.

Reasoning (cont.)

Inductive: generalize 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.



Abductive: 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.

Problem solving

Process of finding solution to unfamiliar task using knowledge.

Several theories.

Gestalt

- problem solving both productive and reproductive
- productive problem solving draws on insight and restructuring of problem
- attractive but not enough evidence to explain 'insight' etc.
- move away from behaviouralism and led to information processing theories

Problem solving (cont.)

Problem space theory

- problem space comprises problem states
- problem solving involves generating states using legal operators
- heuristics may be employed to select operators e.g. means-ends analysis
- operates within human information processing system e.g. STM limits etc.
- largely applied to problem solving in well defined areas e.g. puzzles rather than knowledge intensive areas

Problem solving (cont.)

Analogy

- novel problems are solved by using knowledge from a similar domain in new domain — analogical mapping
- analogical mapping may be difficult if domains are semantically different

Skill acquisition

Skilled activity characterized by

- chunking — lot of information is chunked to optimize STM
- conceptual rather than superficial grouping of problems — information is structured more effectively

Skill acquisition (cont.)

Model of skill acquisition: ACT*

3 levels of skill

- general purpose rules to interpret facts about problem — knowledge intensive
- specific task rules are learned — rely on known procedures
- rules are fine-tuned — skilled behaviour

Mechanisms for moving between these

- proceduralization — level 1 to level 2
- generalization — level 2 to level 3

Skill acquisition – proceduralization

Level 1:

```
IF cook[type, ingredients, time]
THEN
    cook for: time

cook[casserole, [chicken,carrots,potatoes],
    2 hours]
cook[casserole, [beef, dumpling, carrots],
    2 hours]
cook[cake, [flour, sugar,butter, egg], 45 mins]
```

Level 2:

```
IF type is casserole
AND ingredients are [chicken,carrots,potatoes]
THEN
    cook for: 2 hours

IF type is cake
AND ingredients are [flour,sugar,butter,eggs]
THEN
    cook for: 45 mins
```

Skill acquisition – generalization

Level 2:

IF type is casserole
AND ingredients are [chicken,carrots,potatoes]
THEN
cook for: 2 hours

IF type is casserole
AND ingredients are [beef,dumplings,carrots]
THEN
cook for: 2 hours

Level 3:

IF type is casserole
AND ingredients are ANYTHING
THEN
cook for: 2 hours

Errors and mental models

Types of error

- slips — change to aspect of skilled behaviour can cause slip
- incorrect understanding — humans create mental models to explain behaviour. If wrong (different from actual system) errors can occur.

Individual differences

- long term — sex, physical and intellectual abilities
- short term — effect of stress or fatigue
- changing — age

Ask: will design decision exclude section of user population?

Cognitive Psychology and Interactive System Design

Some direct applications. E.g. blue acuity is poor so blue should not be used for important detail.

However, application generally requires

- understanding of context in psychology
- understanding of particular experimental conditions

A lot of knowledge has been distilled in

- guidelines — see Chapters 4 and 5
- cognitive models — see Chapter 6
- experimental and analytic evaluation techniques — see Chapter 11