

## The brain, cognition and usability

Jaana Holvikivi

The brain, mind and body are united, and human information processing activities connect them in various ways. The brain is not a modular organ that would have separate places for memories, different types of perceptions, language processing, rational and emotional thinking. “The processes of mind and behavior result from the concerted operation of the *many* regions that constitute brain systems, small and large. None of the grand functions of the human mind – perception, learning and memory, emotion and feeling, attention, reasoning, language, motion – arises in a *single* center of brain.” (Damasio 2003)

Impulses entering the brain are processed in an interconnected manner. The brain receives information through all modalities. The information from modalities is processed and compared with the internal, stored information, and combined with the information about the person’s bodily state. Based on the episodic information, the brain decides its actions, partly consciously and partly unconsciously, and initiates movements. The consciousness has to filter an enormous amount of information that the brain receives, and focus its attention to the crucial information. The incoming information is combined and associated by the working memory that forms representations of the situation. The working memory is closest to the concept of thinking, though only part of it is under conscious control.

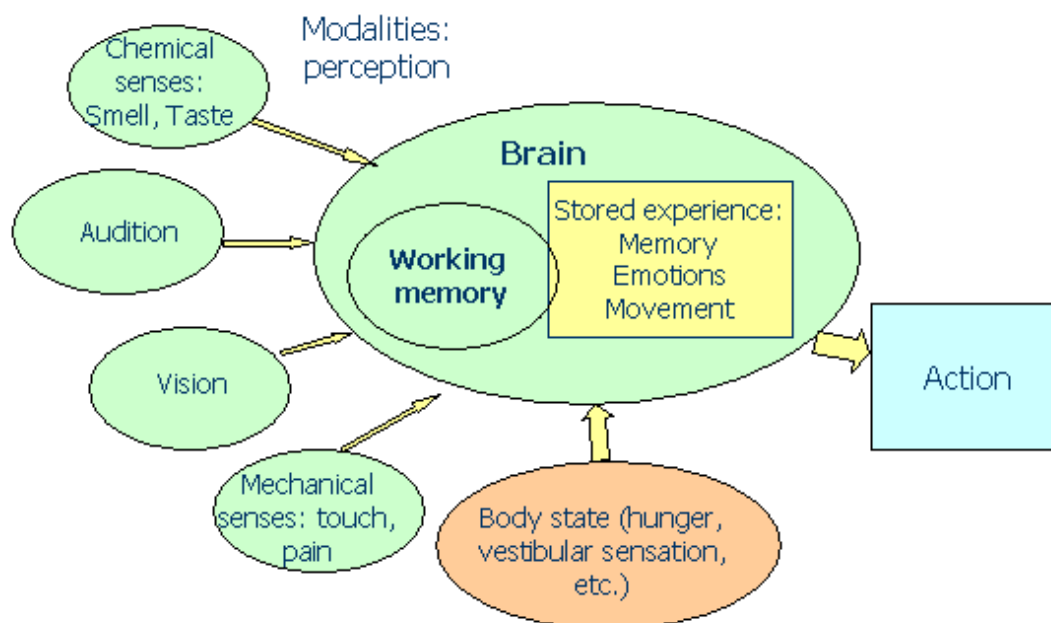


Figure 1: Polymodal perception

The brain has a mechanism of keeping representations active without external input. Memories start to form when the information passes from the prefrontal cortex to the hippocampus from where it is sent to long-term memory in the cortex.

## Memory

The taxonomy of human memory distinguishes between declarative and procedural memory - knowing *what* and knowing *how*. Knowing that an object is called a bicycle is declarative; knowing how to ride on it is procedural. Declarative memory subdivides into semantic (knowing what dentists do) and episodic (remembering seeing a dentist and having a filling) memories.

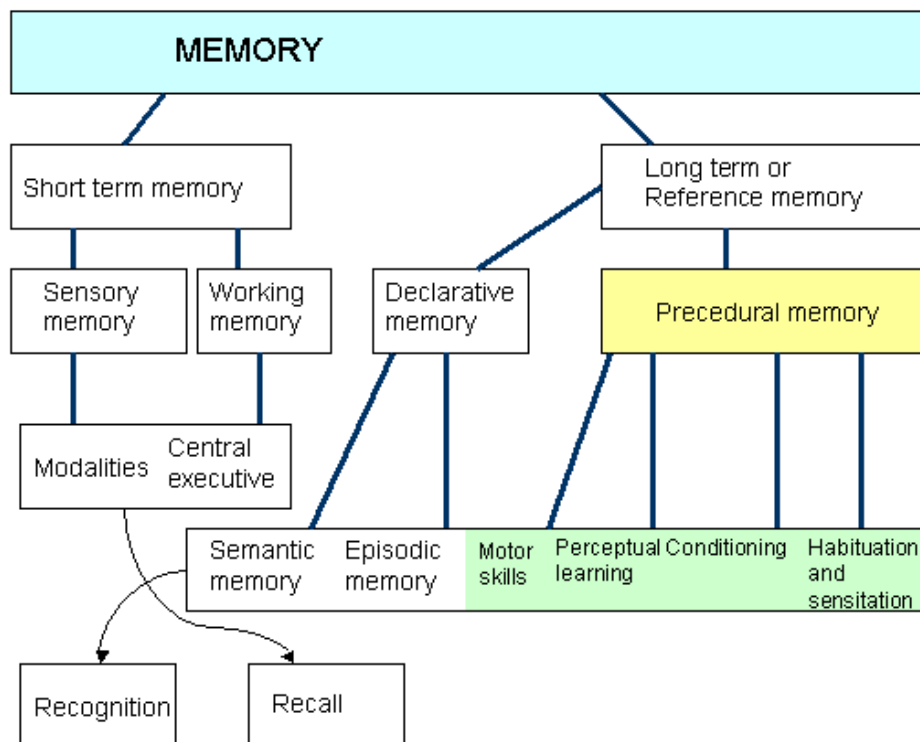


Figure 2: Functional model of memory

Short-term memory has a temporal gradient, which has been tested a lot in psychology: subjects are asked to remember lists of separate facts (numbers, words) and then to recall them. The limit of short-term memory storage is about seven to eight units. However, recalling arbitrary units is different from recalling representations or chunks of information that belong together. Moreover, recognition is much easier than recall.

The human memory is inaccurate and unreliable, because it cannot be protected from changing. Sensory and motor skills are located in specific areas of the frontal lobe. Because these skills modify the brain areas permanently, they are retained through life much better than semantic information. Much of the learning of movements happens unconsciously.

Timing of activities is decisive when storing information to the memory. In an experiment, where fruit flies were trained to avoid a particular odor, it was found that massed training, giving the flies the same number of training experiences in rapid succession, did not produce an enduring memory; but spaced training, with session intervals of 15 minutes, did produce. Distributed practice works better than massed

practice. Spreading out your study is better than cramming. Also, having a break and relaxing after intensive working often releases creativity and yields a solution to the problem under consideration. There is a specific time interval, about six to eight hours after training, when the neural activity is particularly strong, and lasting memories are formed.

Memory consolidation takes place while we sleep, and it takes up to a few weeks of repeated rehearsal for the molecular reactions controlling gene and protein synthesis to record long-term memories. If the interval between rehearsal sessions is too long, the short-term memory will have weakened too much to benefit from repetition.

In a sum, there are several time points that are decisive in learning and memory consolidation: the first minutes when the information circulates to hippocampus, then the five to six hours for the active consolidation, next sleep is needed, and finally a two week consolidation period.

### **Emotion and cognition**

It has been shown in many studies that happiness and positive mood increases flexibility in problem solving. Affect, cognition, and motivation influence one another. Meaningful and emotional information is retained better in memory than purely factual information. It does not necessarily indicate, however, that the memories would be accurate in relation to factual events, especially if they are connected to strong feelings. On the other hand, memories are better retained even if the factual information is neutral but it was presented in an emotional context. Emotional events are bestowed with special prominence in memory.

Stress weakens attention and working memory. It rises levels of noradrenalin, dopamine, and cortisol in the brain, and induce neuron destruction in hippocampus. The production of new neurons in hippocampus is also reduced under stress.

Laughing has numerous benefits for health as well as learning. Laughing reduces stress because the level of cortisol is reduced and levels of epinephrine decrease. Moreover, laughing has been shown to improve memory in psychological tests (long-term memory, recall one week later). Students who watched an episode of "Friends" after studying for an exam, got 20% better grades than the control group that did not have fun.

### **Attention**

Conscious thought is not simply being conscious of something that otherwise goes on unconsciously, it is a special kind of activity. Paying attention is a crucial part in it. Attention is a way of devoting our limited abilities to the most important information and actions. People are not good in doing many tasks simultaneously, usually, doing one task or attending to one stimulus interferes with another (such as having a phone call when driving increases the risk of not noticing the traffic). Also some brain conditions such as the ADHD, stress, or age can cause particular problems in attention. To improve concentration, reduce distraction and create a relaxing environment.

## Thinking in patterns and narratives

Especially in engineering, it is often assumed that logical and rational thinking are natural to the human brain, which however, is not the case. Logical and sequential thinking are exceptional modes of thinking that need to be learned by long training. Much of the thinking is analogous and heuristic; humans perform very little step-by-step algorithmic deduction. In problem-solving, application of an algorithm always guarantees the correct answer, but it requires a well-defined problem. Heuristic methods include rules of thumb and 'means – ends' analysis that includes an incremental search of the problem space.

Thinking and problem solving processes have been studied extensively, for example using verbalizations and think-aloud studies. Think-aloud protocols became one of the standards in usability studies, as well. However, they are better in describing step-by-step action than heuristic or analogical thinking, or random exploration.

Computer is not a fitting metaphor for human memory. Computers deal with organized information, whereas humans deal with meaning, narratives and complex patterns of a multimodal reality.

Lucy Suchman performed an analysis of human – photocopying machine communication in the early years of Xerox machines (1983). The designers of photocopying machines relied on hierarchical menus and a couple of buttons that had to be pressed for a selection. In Suchman's experiment, two humans and the machine ended up in misunderstanding because the humans had made one wrong selection. The machine has certain states when it is only able to do certain actions; as a result of wrong user selection the desired state (action) is not accessible. The machine cannot offer appropriate selections or communicate its status.

Humans and machines differ in certain aspects significantly in their modes of communication. Humans are:

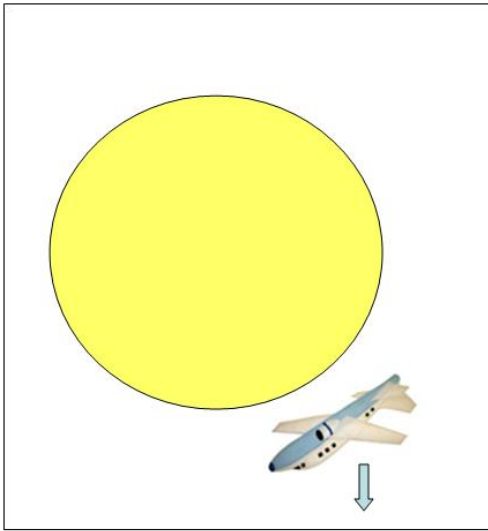
- open to any action (wide range of actions any time)
- flexible, open-ended

Machines:

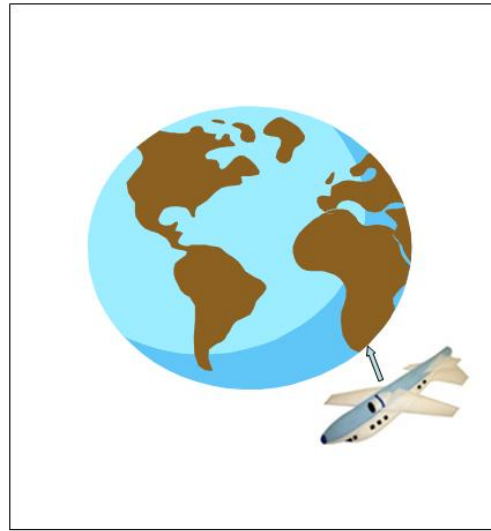
- proceed in preconceived sequences,
- cannot step back and see all possibilities unless instructed to do so,
- follow navigation paths.

Users interpret visual cues according to their experience and mental frameworks. A novel interface requires adaptation. People create structures of their environments that bias the way they interpret things.

Does the airplane fall?



Mental framework 1



Mental framework 2

## **E-learning environments and visual design**

(Based on David Kirsh: Metacognition, distributed cognition, and visual design.)

Kirsh defines intelligent action as deciding what to do next; it is normally supported by the environment that is imbued with cues, constraints, and indicators that reduce the complexity of decision-making by providing resources. If the environment is well-designed and well-known to the person, intelligent action is greatly facilitated. People are not particularly good at tasks that require abstract reasoning or intensive recall but they excel at using resources in systematic but creative fashion to work their way to solutions.

Much of the success of e-learning environment turns on the dynamic relation that emerges between learner and environment: how well students interact with their environment; how well they read documents; how well they explore concepts, facts, illustrations; how well they monitor progress; and how well they solicit and accept help. The success depends on the details how tools, contents, and supports are implemented. Features that go unnoticed or cannot be found, are not used.

Visual design is more than an aesthetic choice, it affects the usability, simplicity, and clarity of the content, and the way users conceive of interactive possibilities. Good design helps to manage student attention and train students to expect semantically important cues such as topic sentences or useful summaries to be visually prominent.

A good interaction design displays cues as possibilities for action to the user; action affordances of a space. The user is guided by visual design, aesthetics, and the range of possibilities that should support the user in her choices. Visual perception is active

and interactive, and actually involves an integration of visual and motor systems. What we see is not independent on how we move. The challenge of the design is to figure out how to guide and direct users by structuring the affordance landscape (opportunities for action; possibilities).

However, visual design is not all there is to interactivity design. Designers must understand how to decompose a functionally complex system into a collection of functionally simple systems:

1. Good visual designs are cognitively efficient (easy to understand).
2. Good visual design supports helpful workflow. Because learners typically have multiple tasks to perform, they need to plan, monitor, and evaluate their progress.
3. Good visual design is about designing cue structure.
4. What goes together semantically, goes together visually.