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Content

Abstract

Cognitive psychology became more and more important during the last decades. It is involved also in other branches of psychology and has changed them. But also other parts of social science are being influenced. Thus, new knowledge about learning influences pedagogy. But even new sights about attention are important for completely other realms, such as marketing.

This shows how important cognitive psychology is. The purpose of this thesis is to introduce some parts of cognitive psychology: topics such as attention, consciousness, memory, learning, thought and language are illustrated. There are also shown some methods that are used in mental processes: algorithm and heuristics. The properties, advantages and disadvantages of them are explained. A chapter about intelligence rounds this thesis off.

1 Introduction

The term 'cognitive' or its noun 'cognition' is borrowed from the Latin expression 'cognoscere' which means 'to know'. Bought into psychology it is used for the branch cognitive psychology. It means here not just everything that deals with knowledge but with concepts like mind, reasoning, perception, intelligence, learning and like memory, attention, action, problem solving and mental imagery. Cognition is an abstract object that is not be able to investigate directly but only by observation others.

There are a lot of similarities between how we process information and how modern technologies process information. In a very theoretical way it is even equal. Moreover, a computer is much faster, more reliable in processing given information. That is the reason why more and more computer replace erroneous human worker in our factories.

Both - computer and human brain - uses either algorithm or heuristics to process high level information. These two method can be seen in several sections, such as problem solving, reasoning, comprehension of languages. They appear there independent on the section and accompany them like a leitmotif. They are introduced in the according chapters here.

But human beings are not only able to process new or already existing information but they are able to create new ideas and make personal decisions. Insofar, cognitive processes are much more richer than 'just processing machines'. A good example for such a information processing machine is a roboter that can walk, receive input from the environment and process it but is never be able to have own desires or ideas. Here start the differences between a merely machine and a living creature. Such desires or ideas are build in the brain as cognitive processes. We combine stored information to new structures and create things as imagine first. No computer or roboter can do that. But since we construct computer and roboter we are able to evaluate how much cognitive effort our brain is able to perform.

The goal of this thesis is to show how the human brain is able to accomplish the tremendous and difficult assignment of information processing in even different and disjunct partitions. How is our brain prepared do achieve them conveniently?

2 Definition

This thesis consists of six parts: Consciousness/Attention, Memory, Learning, Thought, Language and Intelligence. Each component is here presented shortly now:

Consciousness/Attention

In order to interact to our environment, first, we must be able to receive information. That is the task of our senses. But the received information must be processed, that is, we must be aware of what is going on around us. This is the state is consciousness. If we cannot process it then we cannot notice our environment and act, react or even interact with it. Thus, consciousness it the base or precondition of any mental deliberately processing. However, there is too much input and we need to filter out useless and unimportant information. This is done by attention. Therefore, consciousness and attention are very important step for any cognitive process regarding incoming information from outside.

They belong to cognitive psychology as the first steps of mental input information processing. Both terms, consciousness and attention, are introduced here.

Memory

After receiving such a huge amount of information be must encode, store and - retrieve - it in order to reuse it in a reasonable way. According to the theory of Richard Atkinson and Richard Shiffrin (1968) there are three different stores which are introduced in this chapter. Each part of the memory encodes, stores and retrieves information, but in different ways, duration and capacity. When the importance is high enough then it is transferred to the next part until finally it is stored in the last one. It is also mentioned how we can improve storing information.

Memory is a part of cognitive psychology because we can only do mental tasks on information the is not volatile and - therefore - not existent. It were not possible to compare any information if it were not stored at any place.

Learning

In this chapter the two types of conditioning according to Pawlow, Thorndike and Skinner are introduced: Classical and Operant Conditioning. At the first sight they seem nothing to do with cognitive psychology but they are also based on mental processes. They require cognitive capability as well. While conditioning some utilities can be employed, such as reinforcement or punishment. There is also another type of learning that is based on observation of others and imitation - social learning. These kind of learnings are not based on behaviorism but on cognitive processes.

Thought

Our daily thinking is categorized by psychologists to problem solving, reasoning, and decision making. In this context, the first time the two important methods appear: algorithm and heuristics. But before, the question is answered how we encode our thinking: in language, imagery or even acoustic. Furthermore, it is shown how we categorize objects in a reasonable hierarchy in order to retrieve it faster at later access.

Problem solving, reasoning, and decision making are obviously mental processes that belong to cognitive psychology.

Language

One of the greatest mastered tasks in the early childhood it the acquisition of the mother language. There is no grammar book, no vocabulary list but just the listening to people around the child. Thus, a child learns only from thinking about the just listened phrases and imitation. But it is also discussed what a language is, actually. It consists of several levels that are processed separately. In order to predict the continuation of a still listened sentences we apply heuristics as well. Another question is how far the own language influences the way of thinking. Does the own language form the thoughts?

Acquiring an language and comprehend a sentence is a pure mental process. Language is an important part of cognitive psychology.

Intelligence

The last chapter in this thesis treated the ability or capability of any mental process that is a human being to perform. The definition of intelligence is somehow difficult if not impossible. Several approaches are done. Thus, some psychologists think that there is a multiple system of intelligences, others divide intelligence in three parts. Intelligence even seems to depend on the external environment: one culture put the emphasis on matters that are completely unimportant in other cultures.

Some methods of measuring intelligence are explained. As result of such tests the IQ and normal distribution are introduced.

3 Consciousness / Attention

3.1 Consciousness

While we are awake and while we sleep a huge amount of information arrives us. If we processed all those informations we would be overloaded and too busy to do something else. Consciousness allows us to filter the most important information and to drop silently the useless signals. We can decide what is important and can concentrate on what we think is essential for us. And we can combine the new information with the already memorized information in our brain to a useful structure.

Thus, we can interpret, analyze current given data, and then merge them together with our experience to adequate activities (Marcel, 1983). First, we can monitor the environment and, second, we can control the resulting functions (Kihlstrom, 1984). The consciousness let us directly control our life, it even protects our life: If a danger approaches it let us know the danger and we can react in the right manner by using the current information combined with our experience. It let us be aware of positive and negative events.

But the consciousness does not work like an input machine where all information is processed in the same way. There are personal and individual differences in how we process the same information. E.g., in the cinema all members of the audience see the same movie (= the same input), but all process it and think about it in a personal way. Thus, the conscious is not a bare instrument like a computer but it is a individual and complex instrument to let us survive in the world.

3.2 Attention

As already said, the consciousness filters unimportant information and let enter important input. We are aware of only few signals. We can decide what is important for us by turning our attention toward a task, all other information is diminished but not totally. While we are concentrated the focus is on one task but all other things are excluded.

3.2.1 Attention on Several Tasks

The interesting question arising here is whether we are able to concentrate on more than one task at the same time. We learned before that we focus on one task. Are we able to focus on several tasks simultaneously? It also clarifies the question how far the left information is filtered out. Several experiments are developed to investigate it.

3.2.1.1 Dichotic Presentation

Colin Cherry (1953) developed an experiment to investigate how we select attention among multiple sources. A subject receives two different messages to each ear and must repeat them right after hearing them. So, he is forced to concentrate on one voice. This situation happens quite often at parties where multiple people talk at the same time and we want to follow a message. The subjects could recall the message from the focused ear but were not able to hear to the second message. But the second message was not completely ignored. At least, they noticed when the voice was replaced by a different gender or a tone. If the unattended message suddenly got identical to the first one, all subjects noticed it. This experiment checked the auditory channel, but there are tests that check the optic channel as well.

3.2.1.2 Stroop Effect

One famous experiment is called stroop effect. Some words of colors are written in a table and the foreground color differs from the word. Thus, it is very difficult to say quickly the right color of the word.

Red	**Green**	**Yellow**	**Blue**
Green	**Blue**	**Red**	**Yellow**
Blue	**Yellow**	**Green**	**Red**

The written word interferes with the foreground color. There are two stimulus and we have to decide at each word what we concentrate on. Sometimes it tilts and we say the wrong word. That is an indicator that we cannot ignore the non-attended signal completely.

3.2.1.3 Counting a Number Chain

During a further experiment (Kahneman, 1970) the subjects were told to perform two tasks: First, they had to listen to a spoken chain of numbers (Example: 4-2-6-8). After a second they had to add a one to that chain and to speak them loud (5-3-7-9). Second, they had to identify a visual shown single letter and to tell the letter aloud after the added number chain. Thus, the sequence was: a) reading the single letter, b) listening to the number, c) repeating the number after one second, d) repeating the letter. The elapsed time between a) and b) was variable. Two depending variables were used: first, the average percentage of wrong repeated letters depending on the point in time of the display of the letter, second, the average percentage of errors while repeating the number chain as function of the point in time of the display of the letter. The figure 1 shows the result of the experiment. The most errors on repeating the letters were done during a thin line of time.

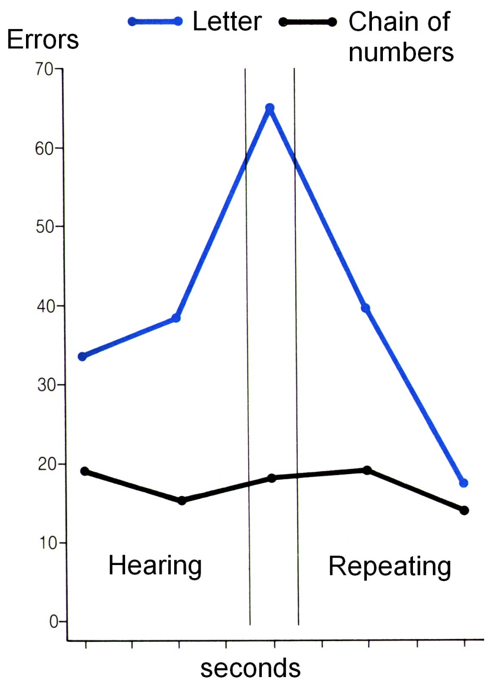

Fig. 1: Chain of Numbers

3.2.1.4 Conclusions

The tests (and some others) allow the following conclusions:

3.2.1.4.1 Attention is a Gradual Process

One noticeable fact during the dichotic presentation was that the subjects recognized personal considerable or important messages on the unattended ear, though. If this were not possible a important information would never be able to get our attention (e.g. danger or a cry for help). That means that there must be an analyze of all received information, even the unattended. Of course, the attended information is more intensive processed and longer in memory (Norman 1968).

3.2.1.4.2 Input is analyzed by Experience

Because of the above mentioned fact there must be a mechanism that checks the input whether there is a meaningful information even in the unattended input. This implies that they are compared with already known information from the memory. According to Neisser (1967), the new incoming input is combined with the information from the memory and then transported to the conscious. Thus, all information that reached the conscious level is already preprocessed. Or, in other words, it is impossible to get information at the conscious level that is not preprocessed already.

3.2.1.4.3 Attention is a limited Function

The chain-of-numbers experiments proofs that we cannot perform more than one task or pay attention to multiple inputs at the very same time. If the elapsed time is long enough we are able to do two or more things at the same time. As long as the slice is wide enough we can distinguish easily two tasks but if the delay gets shorter we get problems to solve both tasks adequate. There is also a difference in what the two tasks are. The more similar the inputs are the more difficult they are to perform (Navon & Gopher, 1979). The famous example is to read and to dictate a text at the same time. It is almost impossible. But it can be trained a bit. After a certain time of training subjects were able to read an write a dictated text (Spelke, Hirst, & Neisser 1976)

3.2.1.4.4 Automation

Yet, there is an exception how we can do even more than two tasks and inputs each. For a given task we can select the necessary input and this input seems to step forward. Thus, subjects can easily search for numbers among a heap of letters, or strokes or crosses under a crowd of check marks. The to be searched items seem to be emphasized. Exactly this emphasis is not controlled, the filtering process appears to be automated (Posner 1982; Schneider & Shiffrin, 1977).

Another kind of automation happens if we do tasks that we are used to do. We do not need to concentrate on those processes any more. A vivid example is the driving of a car. While we learn to drive we are fully concentrated on the different subtasks and the corresponding inputs. Later, when we have learned it, we do not concentrate on the driving but do other things at the same time like talking or discussing to the passenger. Just if we need more attention to the driving (drive into a parking lot) we stop talking and concentrate on that.

Moreover, we are able to do more trained and unattended tasks while we concentrate on a non trained and unknown task.

3.2.1.5 Decisions without Thinking

Because of our ability to do things without our attention we are able to do more than one process. This is a big advantage. But there is a big disadvantage, too. We can decide or perform something without paying attention to it. While we are concentrated on a single process someone else might ask us an (for us) unimportant question and we answer or react without paying attention about what we answered. This effect is called compliance. In an experiment people in the subway were asked to give seat with a given meaningful "because". But, the people gave seat even if the because was a non sense phrase. (Langer, 1978).

Later, when asked why we decided in that way we try to find a reason and find causes that did not exist in reality. We construct an excuse that never happened before (Zimbardo, 1995).

Chapter summary

In this chapter a short introduction about conscious is given, first. Second, the term attention is illustrated. Hereby, the question is whether we are able to pay attention to multiple input and if not, which parameter are used to decide what we pay attention to. After a lot of practice we are able to automate a task and no longer need to concentrate on it. Therefore, we are freed again for further tasks and can perform it unconsciously. And important mile stone to grow up and to be able to do more things at the same time.

4 Memory

4.1 Introduction

To be able to survive we need not only a heart and other organs but we need a construct that allows us to store any kind of information. Meaningful information is always in need during our daily life. Without own storage we were not able even to go or eat. Every action that needs information were not possible to perform. Since we have computer it is easier to explain why we need such a construct called memory. The analogy between memory in general and a computer helps us to understand that a memory is necessary. No computer could work at all without memory. No person could survive without memory. In fact, the human memory is far more complex than any kind of computer. Our human memory is located in our head. In this chapter I provide an introduction about how our memory works.

First of all some definitions.

Memory is not only the place or storage where the information is stored, furthermore, it is the whole process or ability of encoding, storing and retrieving any kind of information. Again, this can be compared with a branch of computer technology: databases. A database stores and retrieves any kind of information. But the memory is far complexer, it realizes the encoding as well. A database needs already encoded information, but storing and retrieving are similar.

Encoding is a process by which any kind of information is changed in that way that it is store able in the memory. Again, an analogon from computer technology: A picture in paper format is not storable in computer memory. First, it must be scanned in, digitalized, and changed in a certain format of bits. This last process is called encoding. Now, it is storable.

Storage is the place where the information is held. Each stored information needs a storage unit. We only have a limited amount of such units. So, it could theoretically happen that the storage is full once. Here we have the same case when a hard drive is full: All storage units (here: sectors and cylinders) are used and no further information can be stored. The storage units and their limits in our memory I am going to explain later.

Retrieval is the process of finding the already stored information again. This process is as important as the encoding and the storage for information that is only stored is useless. It needs to be found quickly in an effective way by using hints and indexes.

4.2 Encoding, Storage and Retrieval

4.2.1 Encoding

The process of encoding is a bit complexer than computer's encoding and it compounds more subtasks. The input is analyzed first. It is compared with already stored patterns (is it a sound, picture or smell ?), thus, its not merely a 'stupid' encoding but an intelligent preprocessing. Many useless input is already filtered out. The input is categorized or classified into already known and general areas or is even recognized as important for later purposes.

4.2.2 Storage

The Storage does not work like a machine. We do not store information like a computer that memorize each single word and never forgets it. Rather, the storing of information demands several processes before it is stored permanently. The more a information is connected to similar or neighbored items and the more it is practiced and repeated the more is the likelihood that we stored it permanently. Many psychologists believe that if an information is stored once it will never be lost again. The only thing that prevent us from remembering is that we cannot find it. And thus, we are at the last important process:

4.2.3 Retrieval

The retrieval of information seems to be simple but it is the biggest problem among all processes. One information might be stored well in the memory but it is useless unless we find it again. The retrieval works better the more ways are built to the information. In other words the more indexes point to the information the more possibilities exists to find it quickly and reliable. One fact is unique: While we retrieve an information it is changed. Each hit of a memory unit changes the content but reinforces the retrieval. Thus, what we retrieve often is likely to retrieve the next time even better as if the way to the info is made wider. There are two way of retrieving information: recall and recognition. The **recall** is a completely self-made reconstruction is stored memory without any hints and the **recognition** is just a comparison between a given input and a stored information. Because is the given input a recognition is easier to perform than the recall.

4.3 Three Stores

One view about how memory works is an approach of Richard Atkinson and Richard Shiffrin (1968). This view is widely accepted but other views are developed either. I will only describe the view of Atkinson and Shiffrin because of its acceptance.

According to them the memory is divided in 3 different stores: the sensory memory, the short-term memory and the long-term memory. These three stores do not have a certain realm in the brain each, its rather a hypothetical structure.. The way of the information goes always from the sensory memory to the short-term to the long-term memory. One fact makes the whole memory process more complex: Each store or stage has their own encoding, storage and retrieval.

4.3.1 Sensory Memory

The sensory memory is the first memory within the memory chain. Here, arrive all information from the senses. This memory gets in action directly after the input but before any process of recognition of pattern. Therefore, this memory is precategorial (Crowder & Morton, 1969). Each sense has its own part within the sensory memory. The visual part is called iconic memory, the auditive part is called echoic memory. The left parts are not as well investigated as the former one. The remembrance of the iconic memory lasts for nearly a half second, for the echoic memory around some seconds (Neisser, 1967). This kind of memory is needed for the recognition of the patterns. If we had not such a memory we would see or listen as long as the physical inputs lasts, there were no 'buffer', too short to process the input contiguously.

4.3.1.1 Encoding

During the first encoding there is already a selection of which inputs are marked as important (not to mix up with a recognition of patterns). While a sportsman is performing the sport he/she does not notice injuries. Later, after finishing he/she get aware of those. Or, a soldier does not notice own wounds until he is off the battle field. These two examples show that there is a selection regarding the importance.

How long and how much can the sensory memory store? According to the experiments of Sperling (1960) we can only store a limited time and amount of input. He presented some lines as shown below containing 3 randomly ordered consonants to subjects for the period of 50ms.

```
F W X
D N W
F Q L
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After showing the complete table he asked to repeat one line that was chosen by an acoustic signal. He noticed that all subjects were almost always able to repeat the chosen line perfectly. He interpreted this result as evident that we can memorize within the sensory memory nine items. In further tests with four consonants and a larger delay he could ascertain the limit of the sensory memory. After a delay of one second the subject were significantly lesser able to repeat the chosen line.

Later scientists enhanced the experiment by testing the acoustic ability to remember auditive input (Darwin, Turwey, & Crowder, 1972) They proved that we can store more acoustic information than we can normally report. This fact is probably necessary to process words and sentences to a semantic meaning.

But why is a limit of one second useful? Or why just a second? Two considerations may give an answer. Firstly, if the time to remember were too short we could not process continuously the input. There were interruptions during our merging of the received input. Secondly, on the other side, if the time to remember were too long the old information would interfere with the new ones. We had an overlap of old and new inputs. An experiment of Averbach & Coriell (1961) gets us to see that. Two rows of eight letters each were presented briefly to subjects. A marker that indicated the location of a target letter was presented either simultaneously or at varying time intervals following the presentation of the letter array. Subjects were to report the identity of the marked target letter. The accuracy of identification of the target letter decreased with increases in the temporal interval between onset of the letter array and marker. During a certain time the subject 'sees' the marker instead of the previous letter. This phenomenon is called backward masking.

During this very first time of processing there is a race of all input against the time. The most inputs loose that race and never reach the short-time nor the long-term memory: if the input is too short and directly interfered by next inputs. Thus, we need a certain time to receive and process successful useful and important information.

4.3.1.2 Conditions for a Transfer to the Short-term Memory

We receive much more information than we can process. Therefore, the sensory memory filters the vast part. What are the conditions that an information is transferred to the short-term memory?

First, we must pay attention to that input. Only if an input is important and worthy enough for us to pay attention to it is able to reach the next realm or level. If this is the case then we select that input and concentrate on it. This step or decision is called selective attention. We select one input out of a multiple amount of inputs and concentrate on it while we ignore the rest of inputs. This input is a candidate for further processing in the short-term memory.

Second, while we perceive an input a pattern recognition takes place. If one input consists of pattern that we can recognize and process to useful information it is available for a longer time in the sensory memory and will we transferred to the short-term memory because it is regarded as important, useful, and helpful.

4.3.2 Short-term Memory

The short-term memory is according to Richard Atkinson and Richard Shiffrin the second kind or realm of memory. In the order of processes of memorizing is lays between the sensory and the long-term memory. As already mentioned the flow goes from sensory via short-term to the long-term memory. Some interesting properties differs it from the other two, sensory and long-term memory (Zimbardo, 1995).

- The capacity of the short-term memory is very limited. Compared to the other two memories it is negligible.
- The duration is also very limited, around 20 seconds, unless it is kept conscious.
- Only in this stage information is processed consciously, the other two are never conscious for us.
- This part of memory is the only one that is able to assemble subsequent pieces of input to a context such as a conversation or a fluent input of visual or auditory input from a speech. We can also follow and adapt to a changing situation by the short-term memory. Only here we are aware of any flow or change. One example: We sit in a restaurant and are talking concentrated. The waiter passes by our table. After a while resounds a loud clangor. Even though we haven't seen the cause we know that is was not caused by a tree or car or whatever but by the waiter. The short-term memory accesses the just received input including information from the long-term memory to interpret the cause of it. (Baddeley & Hitch, 1974).

4.3.2.1 Encoding

As already said, only selected and regarded as important information reaches the short-term memory. But the question is how it will be encoded there. Two kinds of encoding are used: articulatory-acoustic or semantic encoding.

4.3.2.1.1 Articulatory-acoustic Encoding

One method of encoding is the articulatory-acoustic encoding. We rather hold the label of the item in the short-term memory if it is labeled. Even verbal patterns that are received in visual input (=reading) are stored in an acoustic form. Experiments dealing with lists of letters have proved it. Subject were presented an amount of letters like CBTPEGFSYX for a short time. Mistakes of memorizing were done with letters which sound similar (D and T), but not which are written similar (D and O) (Conrad, 1964). During the test no one read or spoke those letters. This proves that we think and memorize in acoustic or language form, not in visual pictures like the form of the letter. But there is still the question whether we use an acoustic code (= using the description of its sound) or an articulatory code (= using the way how to pronounce the word), but in both cases it has something to do with the sound of the item, hence the term 'articulatory-acoustic' is used in order to pay attention to the still existing uncertainty.

Tests with deaf subjects show that we are able to use other encodings as well: visual and semantic encoding, but as healthy people much lesser. (Bellugi, Klima & Siple, 1975; Frumkin & Anisfeld, 1977).

4.3.2.1.2 Semantic Encoding

Keppel & Underwood (1962) made further investigations of the paradigm of Peterson & Peterson (1959) and pointed out that the very first try was recalled even after 18 seconds error free. They observed that these results worsened down to 10% after the third or fourth trial. This phenomenon is called proactive inhibition. It refers to the fact that new information is interfered by old information and thus prevent memorizing them. Wickens et al. refined the paradigm of Peterson & Peterson (1959) again by using even different meanings of 3-letter words. They told the subject now a completely different code after the 3rd or 4th try, not a 3-letter-code but a 3-digit-number. Surprisingly the ability to memorize was again at the level of nearly 100%. Wickens et al. thought that such a dramatical improvement always takes place on the forth trial no matter what kind of information. In other words is that phenomenon more general? This is indeed the case and it shows that a change in the meaning influence the memorizing. This implies again that we use semantic encoding as well because just acoustic encoding would never take care of the meaning. The subjects do not have to be aware of the change of the meaning, therefore the change is not conscious. (Wickens, 1972; Wicken, Born, & Allen, 1963). The processing of the meaning not only the acoustic means that there must be a close connection between the short-term and the long-term memory because recognizing the meaning implies a use of the long-term memory.

4.3.2.2 Storing

The process of storing into the short-term memory is like a bottleneck. Here we can store only very few information. The maximal amount of information is around 7 items. It seems to differ between 5 and 9 items. This limit is very strict. It is not possible to store one item more than usual. If we need to store a new item the first stored will be deleted.

George Miller (1956) found the limit of the short-term memory and it is confirmed by many scientists. A list of coincidental numbers or letters was shown to subjects who were asked to read and repeat right away. All were able to repeat around seven numbers or letters. Some person can repeat only five, some others even nine items.

5 8 3 4 9 5 0 8 6 5 4 8	G J R X O M A Y I P E S V

Fig. 2: Available Space in Short-Term Memory

It is easy to confirm by ourself that there is a limit. We can only store around seven items. More is not possible, even if we work hard at it.

4.3.2.2.1 Processing in Short-term Memory

The limit seems to be too low. How can we memorize longer information, though? There are two ways how we are able to store longer information: chunking and repeating.

Chunking

Chunking means to pool or merge several items to a larger one, that is like to merge e.g. four numbers (2 0 0 7) to a larger item (2007) or 'i n f o r m a t i o n' (=11 letters) to 'information' (=1 item).

Chunking is not limited just to numbers or letters. Each pattern or information can be reorganized to few items. Those items do not necessarily have to have a meaning, but the new structure must be recognizable. Here are some examples given:

19451939191819141871	1945 1939 1918 1914 1871
GMIBMUNESCOUSAWHO	GM IBM UNESCO USA WHO
THISISANORMALSENTENCE	THIS IS A NORMAL SENTENCE

Fig. 3: Chunking

The big advantage is that the short-term memory can store seven items. In this case each word is an item, not just the letters of a word. Thus, we are able to store far more real letters than only seven. It is just a matter of reorganizing. When we merge them together in a reasonable, traceable way we are able to place more information in here. This chunking can be nested, so we can even regard a whole sentence as one chunk. Hereby, the length of the content of one chunk is not important. Of course, this nesting is not infinite, there is still a genetic limit. Lehrl and Fischer (1988) argued in their theoretical framework of information psychology mental power that the capacity C of the short-term memory can be calculated by the product of the individual mental speed Ck of information processing (in bit/s) and the duration time D (in s) of information.

$$C\ (bit) = Ck(bit/s) \times D\ (s)$$

But Chi (1976) and Simon (1972) argued that the limit also depends on the age of the subject. An adult has his limits beyond a child's limit. It might be caused by a more limited structure of its short-term memory.

The real limit cannot be seized into a fixed formula. Those attempts are just approximations. The real limit probably depends on more parameters and is still unclear.

The important point of how much we can store in the short-term memory is how much information we are able to reorganize them into chunks. A adequate example is how much chess pieces a novice and a chess master are able to recall after seeing them for few seconds. While a novice is able to recall around seven pieces, a chess master is able to recall around 25 pieces. He reorganize all given pieces to traceable chunks. This shows, that the ability of chunking can be trained. (Simon, 1974; Simon & Chase, 1973) This fact is applied to learn or memorize more efficient.

Repeating

The question was how to enlarge the very limited capacity of the short-term memory. One way is to reorganize information into items. The second way is to repeat the information.

An insightful experiment shows clearly how far we are able to maintain information without repeating it. Subject were shown 3 coincidental consonants like TBX. They were told to repeat them after a signal. The time between showing and repeating them varied from 3 - 18 sec. In order to prevent a rehearsal the subjects were asked to count down aloud a 3-digit-number three-step-wise until the signal resounded. Thus, they were kept concentrated. Already after an interval of three seconds the consonants were repeated unreliable and after 18 seconds nearly no subject was able to repeat them (Peterson & Peterson, 1959). No one was able to recall them without repeating.

There are two ways to perform such a repeating: maintenance rehearsal and elaborative rehearsal.

Maintenance Rehearsal

The easiest way to keep information in the short-term memory is just to repeat it several times. Thus, we can prevent new inputs to interfere and to kick out our wanted information. It is also a matter of concentration: what we repeat we concentrate on and block other inputs from entering the short-term memory. One big disadvantage of maintenance rehearsal is that the information do not necessarily enter the long-term memory.

Elaborative Rehearsal

To ensure that information enters the long term-memory elaborative rehearsal has to be done.

Hereby, the input is analyzed and bound to already existent information from the long-term memory. Practically, elaborative rehearsal takes place when we process the input in such a way that we combine it other useful information. One example shows this process: A phone number (25365869) is memorizable in (at least) two ways: 1) when we build a calculation (**2536**+3333=**5869**). Here we combine the new information with an mathematical addition that is already known in the long term-memory. 2) we compare the number with the layout of the keyboard of the computer. We type 2536 and then we shift up the finger one row and type 5869. Here we combine the new input with the known layout of a keyboard. Of course, there is no limit in building such ways and every individual has his own preferences.

Often elaborative rehearsal is even combined with chunking. Thus, elaboration is used to construct new chunks. Chase & Ericsson (1981) investigated this process by training a student to remember as much as possible numbers. After 2.5 years of training this student was able to recall numbers with a length of 80. His method was simple: He was a former long-distance runner and compared the numbers with the times for different runnings. Hereby, he used already known information from his long-term memory (=elaborative rehearsal) and constructed new groups of numbers (=chunking). His limitation of the short-term memory was still the same, he was still not able to recall more than seven characters.

4.3.2.3 Retrieval

Once the information is stored we need to retrieve it reliable. Sternberg (1966) tested subjects by a simple experiments and used the speed of retrieval to point out how we retrieve information from the short-term memory. A short list of letters (lesser than 6 items) was presented to subjects. After few seconds one letter was shown to them and they had to decide whether it existed in the list or not and to tell it as soon as possible.. The only parameter was the length of the list and only the time was measured. Theoretically there are two algorithms of finding the information. Parallel or serial searching. Parallel searching means that all parts of the set are checked at the same time. Serial searching means that the pieces are checked one by one. But there are two different serial (sub-) algorithms again. The list could be checked completely (exhaustive scanning) or after finding the searched pieces it stops (self-terminating scanning). The latter is more intelligent because it stops right after the first letter in best case. So, the run time is O(1) in computer science notation. In the worst case all items must be checked. Then, the run time is equal to the exhaustive scanning because the algorithm must go though the entire list. Thus, the run time is O(n). It is interesting that Sternberg found out that we use the exhaustive scanning algorithm. This use is not optimal, but we can afford the wasted time since the list is never longer than 7 +/- 2 items.

4.3.3 Long-term Memory

The long-term memory is that part of memory where we keep all kind of information since we were born. Again, this part is divided in three sections: encoding, storing and retrieval.

4.3.3.1 Encoding

The long-term memory encodes different than the short-term memory. The reason is that the long-term memory has different tasks and needs more possibilities to retrieve the information. Long-term memory is not just a big box where information is stored but it is able to solve problems and to create new ideas and to apply old experience to sort new input. This encoding is done semantically.

4.3.3.1.1 Semantic Encoding

Different to the short-term memory where information is subsequent stored, here all information is stored like in a library or in a filing cabinet, which means that all information is stored parallel and ordered according to their meaning. Often the data has more than on meaning. This fact is represented in multiple indices. Therefore, there are more than one way to retrieve the data.

One evidences prove that data is stored here according to their meanings. It is very likely that sentences are not stored literally like a file on an audio tape and recalled literally but rather the meaning and content of a sentence (Bransford & Franks, 1971). Furthermore, a sentence that someone has not understood is not recallable as contributing item for further synthesis.

There are some ways to organize such an index or sorting. But here we see that chunking and elaborative rehearsal are preparations for a creation of such an index:

- Find an adequate headline for a topic. If we find something recapitulating for a given topic or context or if it is given we can handle this fact easier and make it more to a sortable and comprehensible unit.
- Grouping. Supposing that there are several items it is easier to group them into several categories. We do that daily but it is the art to group them efficient and intelligent. If a new item has to be added we can either append it to an existing group or create a new group.

Basically, an item is supposed to be processed in such a way that encoding, storing and retrieving is matched, balanced or aligned as much as possible. The more data is processed accordingly the more it is likely that it will be utilizable later (Zimbardo, 1995).

4.3.3.2 Storing

The long-term memory stores not only input from outside but also thoughts and creative ideas.

Thus, it stores more than the merely information from the world outside. All combinations and connections from mental production are hold here as well. To fulfill this high requirement the long-term memory is divided in several sections according to Tulving (1972): The procedureal memory, the declarative memory, whereas the declarative memory is divided again in semantic and episodic memory.

4.3.3.2.1 Procedural Memory

In this part of memory there is information stored about how we make things and do tasks, either concerning cognition or movement or perception. (Anderson, 1982; Tulving, 1983) Each acquired skill is basically a sequence of subsequent actions. Those subsequent actions are stored as single unit and are gained by a lot of practice (Bandura, 1986).

They require a lot of practice which means they are difficult to obtain but even more difficult to forget. Once we can swim we can swim forever even after may be 20 years or longer. We probably just need a very short time to get used to it again, but actually we still know how to do it.

Once we have learned a skill we don't need to pay attention on how we do it, we can concentrate on other things, moreover paying attention on it again is even going to disturb the automated skill.

4.3.3.2.2 Declarative Memory

Again, the declarative memory is divided in two parts: the semantic memory and the episodic memory. The declarative memory contains facts that we have to recall consciously.

Semantic Memory

The semantic memory is like a encyclopedia or a library. All abstract or theoretical information is stored in here. Here are not stored personal information or own remembrances rather facts which are valid for a general range like history or formulas of natural science.

Episodic Memory

This part is just the opposite of the semantic memory. In here are all personal remembrances are stored. Here is hold not just the fact but also the time and the context of an event. But often, we remember a fact (that belongs to the semantic memory) via a personal event, such as we remember a fact about history via the lesson at school when the teacher dealt with that subject. In such a case there are connections between the semantic and the episodic memory.

It is very interesting that we with each recall from the episodic memory even more save in the memory. We save the remembrance on the remembrance as well. This additional saving contaminate the existing information and veil it. Therefore, the more we remember a personal event the more it becomes unreal.

4.3.3.3 Retrieval

Like the short-term memory the stored information must be retrieved in order to use it for further tasks. The question is just how we retrieve them. Many scientists believe that no information is lost or forgotten but we no longer know how to retrieve them (Linton, 1975).

We have two kinds of remembering from the long-term memory: free recall and recognition.

4.3.3.3.1 Free Recall

A free recall from memory means a complete self-constructed report or repetition of stored information. We only got a command to reproduce it (by others or by ourself) and start recording what we know unless we don't remember any more because of the lack of indices. The problem here is that we do not have any cues from outside. Thus, if there is not path at all to the information or we cannot find it then we will never be able to recall them.

As a test of an exam it refers to a own written description or article out of the memory without any cues like dictionaries or encyclopedias.

4.3.3.3.2 Recognition

The main difference to a free recall is that we receive an input from outside first and then we just need to compare it with already existent knowledge. If there is no knowledge we cannot recognize it and have no result (even not a negative result), but if we know it we can answer a result.

As a test of an exam it refers to a multiple choice task.

The recognition seems to me easier because we "just" compare a given input to a stored item but sometimes if the inputs are very similar it is almost as difficult to remind as a free recall because it approximates to a free recall.

If we slow down and stagnate in an oral exam - that is a free recall - and the examiner gives us a cues and we can continue fluently then it changes from a free recall to recognition, or in other words the cues provides us a path to the actually lost knowledge.

Chapter Summary

In this chapter the memory is introduced. After providing some explanations about basic expressions, each memory is presented in detail. Most in detail explained is the short-term memory for several reasons, First, it is the last step before entering the long-term memory and, second, it is the only memory that we experience consciously. It is, so to speak, the connection between the external and the internal world. Different types of encodings and the - very limited- way of storing in chunks is mentioned but also the ways of improvements to increase this limits. In long-term memory the different kind of encoding and retrieval is described.

The memory theory of Atkinson-Shiffrin is only one way to explain how our memory works. The problem is that we cannot look inside the memory and see while it work how it works. Only experiments from outside can provide us an idea. But even the results have to be interpreted. Thus, some theories are made and accepted, as long as they are plausible and can explain the memory in an more easy way.

Modern technological devices are very helpful to look inside a memory, but the memory or thinking itself is still concealed. Here, we ought to have a machine that works in the same way like the memory, that can decode memory's information before it is already decoded by the memory. Thereby, to make such a machine we have to know the code first. But, if we already know the code we no longer need to construct such a machine. This means, we will never be able to understand completely how our memory works.

5 Learning

The type of learning treated here is not a continuation of the last chapter. It is rather a description of how we learn behavior, habituation, and our character. Thus, the meaning of learning here is not an increase of knowledge but a stable change in the behavior caused by experience from the result of a certain action. The first and pioneering experiments performed Iwan Petrowitsch Pawlow

5.1 Classical Conditioning

He studied the behavior of a dog that was presenting food. He found out the following generalized phenomenon:

The first step (A) is an already known and normal unconditional reaction (UCR) of a subject to a unconditional stimulus (UCS) like here a salivating dog after presenting it some food.

At the same time a different stimulus that has nothing to do with the first one or the reaction is presented (B). This happened several times. In our example a bell is ringed while presenting the food.

After a while just the second stimulus is presented and the subject shows the same reaction like to the first stimulus (C). Thus, the unconditional reaction changed to a conditional reaction (CR). The learned conditional stimulus (CS) is an actually neutral stimulus. The dog in Pawlow's experiment salivated after the ringing bell alone.

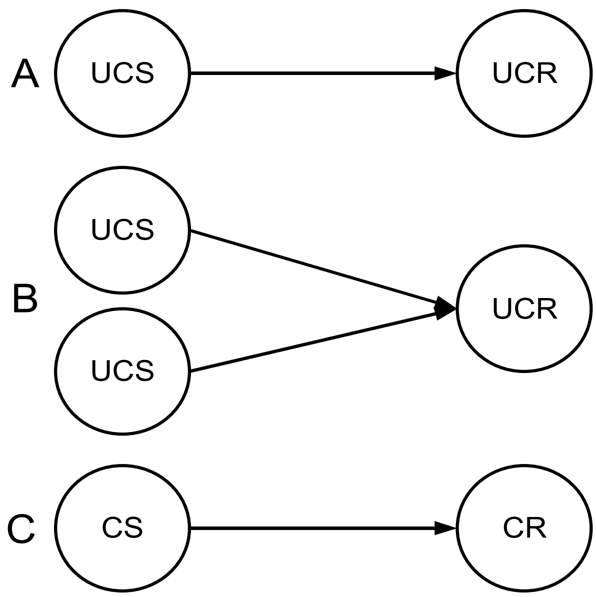

Fig. 4: Classical Conditioning

The conditional reaction is not learned right after the first occurrence of both stimuli. The more they are presented together the more is the likelihood that the conditioning is more stable. This process is called acquisition. But the conditional reaction might not necessarily last forever. After a while the subject 'learns' again that the reaction is in vain and is going to loose it. This phase is called extinction.

Another parameter of a successful conditioning is the time between the two stimuli. The optimal time interval is zero. But a tolerance is permitted depending on the kind of stimuli. Some stimuli might have a time delay of up to a minute, others must take place within a second.

If a subject is conditioned and suddenly a completely other conditional stimulus is presented the subject shows no reaction. The more the conditional stimulus resembles the original conditional stimulus the more likely the subject reacts. He generalizes the stimulus. Or, the other direction, the lesser the similarity the more the subject discriminates and the lower is the likelihood of a conditional reaction. Thus, generalization and discrimination are the two counterparts of how a subject reacts to a third stimulus.

5.2 Operant Conditioning

Nearly at the same time like Pawlow, Thorndike (1898) experimented with cats. But he did not pay attention to reaction to given stimuli but to responses to own actions within a given environment. He presented not a second stimuli to a first one but just the first one beyond an obstacle and observed what the cats would have done. After some trial and errors the cats have overcome it. Skinner (1938) refined the experiments and was able to teach subject almost any kind of behavior.

The learning is possible by using rewards after any wanted action (=operant). Operant conditioning means the change of the probability of a behavior to a wanted direction.

5.2.1 Feedbacks

Such a reward or - more general - feedback can be a reinforcement or even a punishment and motivates the individual to repeat or to avoid the behavior.

5.2.1.1 Reinforcement

We learn what be will rewarded. Such a reward reinforces the subject to do the action again, or increases the likelihood that that action will be repeated. Such a reinforcement does not necessarily be a feedback from outside. Already, the knowledge that the behavior is right is a reinforcement. There are positive and negative reinforcers.

5.2.1.1.1 Positive Reinforcement

A positive reinforcer provides a pleasant atmosphere or gives a comfortable feeling. Therefore, it increases the motivation to do the very same again or even to improve the action in order to receive a more positive feedback. Such a positive reinforcer from outside might be a smile, a praise or a compliment. The action and positive reinforcer together as a pair are called positive reinforcement.

5.2.1.1.2 Negative Reinforcement

The result of negative reinforcement is the same , namely the motivation to repeat the action, but it is based on the withdrawal of a displeasing stimulus or situation. For example, if a student does the homework concentrated then it is done more quickly. Here, the action is the performing of the assignments, and the unpleasant situation is the feeling not be able to be free, the reinforcer is the knowledge that it can be done more quickly. When he is ready the situation changes to a more pleasant one.

5.2.1.2 Punishment

The opposite site of feedback is punishment. This is necessary when the individual does not act in the wanted way. Thus, this action is to be diminished. The negative feedback helps that the action disappears. Hereby, the likelihood of a repeat decreases because the individual excepts again the negative consequence. As well, there are two different kind of punishment.

5.2.1.2.1 Positive Punishment

A positive punisher appears when a unpleasant stimulus is given or a unhappy situation takes place. Such a positive punisher might be a scolding, a hit, a laugher or extra work after an unsolicited action.

5.2.1.2.2 Negative Punishment

Similar to negative reinforcement negative means a withdrawal of a stimulus. Here, it is the withdrawal of a pleasant stimulus such as the opportunity to watch TV or playing games with friends.

The punishment leads to avoid a situation. It is also called aversive conditioning because the individual tries to escape of something by an aversive stimulus.

5.2.2 Differences to Operational Conditioning

There are some basic differences between classical and operant conditioning.

The individual is in classical conditioning rather passive. He reacts on a stimulus and has no own proactive initiative. In operant conditioning he acts and try to find a solution to a given environment. He even interact with it in order to find a solution.

In classical conditioning there is always a pair of stimuli, one unconditional and one conditional, whereas in operant conditioning there is no stimulus at all. Of course, there is the environment providing stimuli but not an active emphasized stimulus.

In operant conditioning the motivation is caused by reinforcement or punishment. Classical conditioning does not know such feedback.

Operant conditioning is far more important for our daily life: We use it for others (like our children) and others apply it to us (like colleagues or the boss) but often not in an optimal way.

5.3 Cognitive Influences

In conditional and operant conditioning come behavior, stimuli, interaction and consequences to the fore. Each kind of learning is eventually a act of cognition because the just observed stimuli or input must be remembered and interpreted but here the behavior is in the foreground (Bandura, 1976; Miller & Dollard, 1941). But there are some kind of learning that are based on cognitive activities. Some of them are introduced here.

5.3.1 Social Learning

This kind of learning is very common, too. Social learning or observational learning starts with the simple observation what others do. First, the individual is not performing directly but only watching passive. Compared to the conditioning types no learning is to expect. Despite, learning is in effect.

Bandura (1965, 1969, 1986) tested in numerous experiments that already children learn by observing adult's behavior. They just imitate the featured actions.

During the most famous experiment, Bandura divided children in three groups and presented all of them a video clip. All children saw a man who punched or kicked a bobo doll. Later in the film shown to the first group, the man was rewarded, in the second film he was punished, and in the third film he experienced no consequences. Right after the film, the subjects were asked to play with such a doll. The children of the first and third group copied that man. Children of the second group played the most less aggressive.

Four depending processes are necessary to learn by observing.

- First of all, the individual must pay attention to the happening. Again, such a paying depends on the personal structure of the individual: is it attractive enough? does it have a adequate level to concern about? what is the own state?

- Second, the model behavior must be stored in the memory. Sometimes, this period of time might be very long, until a adequate opportunity to perform is given.
- Third, the motor action must be reproduced out of the memory. No own practice is possible because it is the first time he acts in that way
- Fourthly, the subject must be motivated enough to perform and to imitate the former seen action.

Now, the question arises what and how can increase the motivation. But this question is not discussed here.

5.3.2 The Cognitive Map

Some situation are not explainable by merely stimuli and behavior structures. Tolman & Honzik (1930) performed some experiments with rats that were to find a way in a maze to their food. Several ways were possible. These ways had different lengths. After closing the easiest and shortest way by imposing the lock B, the rats went without any doubt and error the longest way (way 3). They must have learned a cognitive map of the maze before. There was no certain stimulus that lead them to the food, all ways looked the same. Thus, they were not able to distinguish the right way from the others by a unique stimulus.

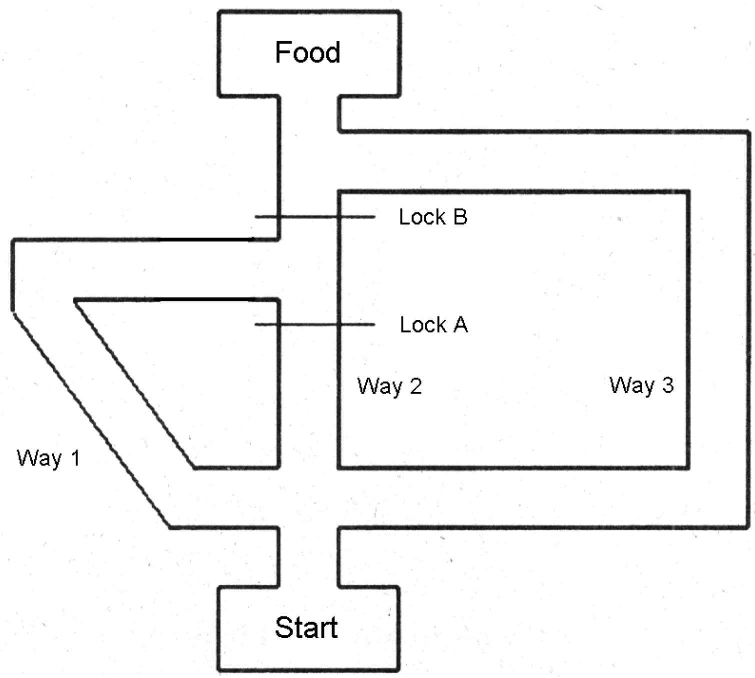

Fig. 5: Cognitive Map

But not only rats - also human beings - use cognitive processes to solve problems. Suppose, there is a problem to solve that we cannot touch or try and error. We can only analyze the problem in our brain and synthesize a solution virtually. This is a clear cognitive process. This matter is introduced in the next chapter.

Even the conditioning is a cognitive process. The subject must

- process information in an active way
- scans the environment for significant events
- memorizes many properties in the memory
- organizes and integrates the new information from outside is in a beneficial way
- decides what is to do based on the new information combined with old information from the long-term memory

This changes the point of view from a behavioral learning to a cognitive learning. Behavioral learning emphasizes the physical stimulus and the environment, cognitive learning emphasizes the internal process necessary to perform such a task. (Spada, Ernst, & Ketterer, 1992). Such a change in researcher's thinking took place in the last 30 years and changed the aspects of learning, thinking and memorizing. Also, neurological processes became more important (Garcia & Garcia y Robertson, 1985; McGaugh, Weinberg, Lynch & Granger, 1985; Thompson, 1986).

Chapter Summary

This section about learning start with the two kind of conditioning. At the first sight they are behavioral but they demand a tremendous cognitive effort to be performed. Actually, from the internal point of view they are cognitive tasks. In operant conditioning the two feedbacks - reinforcement and punishment - are explained more deeply. The third kind of learning - social learning - that is a merely cognitive process as well is introduced next. The memorizing of a cognitive map round this chapter off.

6 Thought

In our daily life we think nearly every second. Psychologists define a thought or thinking in a different, more precise way. Thinking is a conscious and controlled concern in order to reach a certain goal. Thus, thinking can we applied by solving problems, finding a decision or a jugdement, and reasoning. These three parts are discussed in this chapter. But first, the structures in which we think are illustrated. Which methods and concepts do we use to progress such tasks?

6.1 Cognitive Structures

During a day we receive numerous signals and inputs from outside. The brain were unable to process such a tremendous amount of information if there were not special filters that allow to pass only useful information. But not only the first filter are necessary, also we need to catalogize and organizes the input into classes.

6.1.1 Conceptual Thinking

Each individual, not only human beings, is different. Each tree, each animal differs from the next. Again, each situation differs to the former one. If we considered each case as a single and unique case it were each time a brand new situation and we could newer use already learned solutions. That is not only impossible, it were even dangerous. We could not escape a danger because also each dangerous situation is different.

Therefore, we need a technique to organize and classify each new input and to add it in a reasonable way to the already existing information.

Already little babies are able to categorize objects of the environment. We have (an already built) class of, for example, 'games'. Each game is different but we sorted them to a class because there is a certain similarity. We have created a set of concepts which we have ordered all objects, ideas or situations in.

But we build not only classes, we build a hierarchy as well. The 'game' we can organize in a tree with a root, vertices and leafs. The figure 6 shows such a hierarchical tree using the example game.

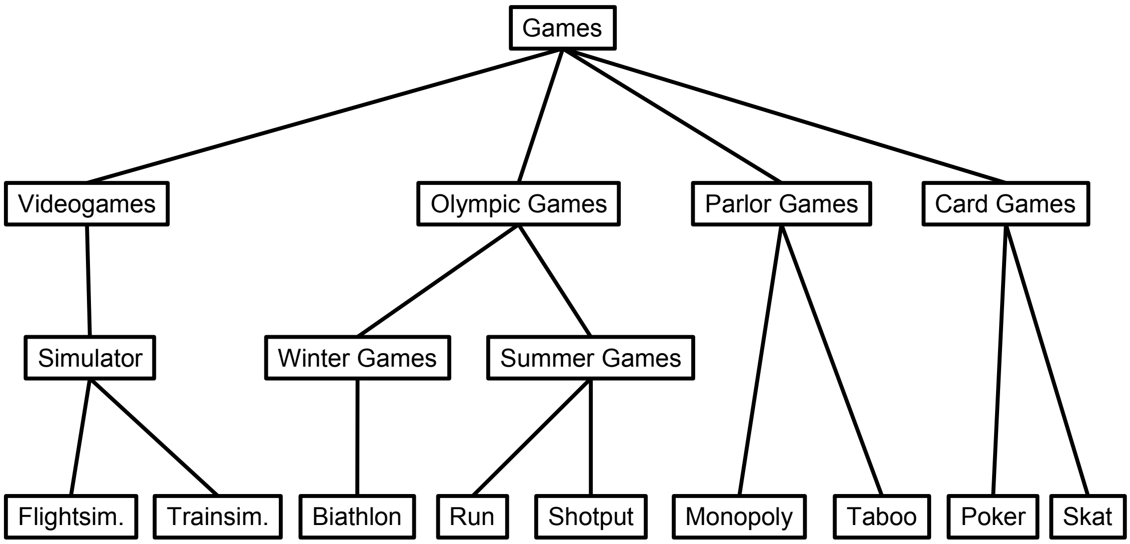

Fig. 6: A Hierarchy of the Term 'game'

If we receive an input that does not fit in any concept we have two ways to organize it:

First, we interpret the new item by sort it into already existing classes. This process is called assimilation. Second, we enhance a very similar class or even create a new structure until the new item fits well and accordingly. This way is called accommodation. We always apply both ways to integrate new information into old knowledge in order to use both in the future. The right balance between assimilation and accommodation is important.

But also for retrieving such a classification is important. It helps us to find an element much fast as if it were unorganized. But not all elements in such a set are regarded equal. We find a typical member of a class faster than an untypical (Kintsch, 1981; Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976). Moreover, we find a element faster if we search in the right or next higher level of the category. We are able to answer faster when we are asked to find the 'Poker' under 'card games' then under 'games' (Rosch, 1987)

6.1.2 Non-language Thinking

While we are thinking we use our language to express what we want to say in order to reach our goal. A thought is composed of the language we use daily. But we can/must think without language sometimes (Steinberg, 2000), E.g. when we have to imagine an observed object or a spatial item. Those imageries cannot be represented by any verbal language.

6.1.2.1 Visual Imagery

Subjects were coincidentally presented a letter in different spatial order. They were to be identified as real image or mirror image as soon as possible. The more the letters are turned around the more time took it to decide whether it is a mirror image or not. This time delay depends on the rotation and is a proof the we turn mentally the image back upright in order to decide it. Hence, this is a proof that we also think imaginary (Shepard & Cooper, 1982).

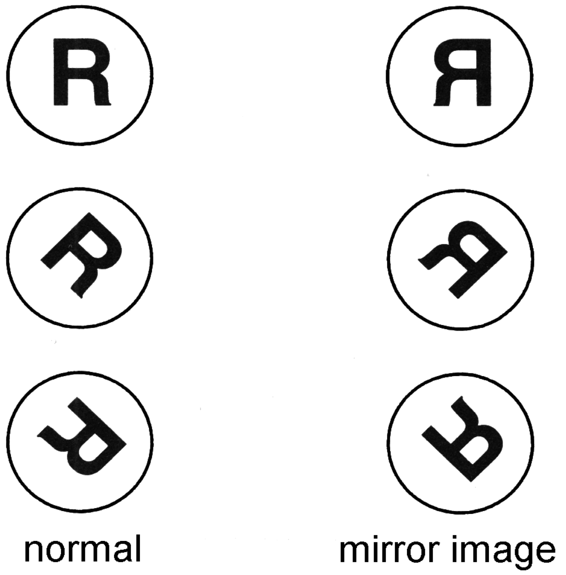

Fig. 7: Turned Letter

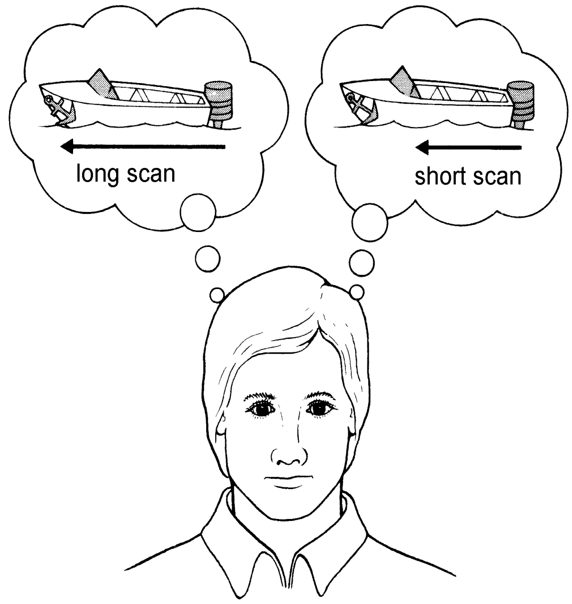

Fig. 8: Scan of an Image

During another experiment subjects were shown a boat for a short moment. Shortly after seeing them, they were asked to emphasize on the motor of the boat. When the subject pay attention to the motor they were asked to decide whether there is a wind shield. As next question, there were asked whether there is a anchor. The anchor was at the other end of the boat, it took them longer to decide whether there is an anchor than to decide whether there is a wind shield. The reaction time was slightly longer. Obviously, they scanned the boat in their mind from the end to the top (Kosslyn, 1980). This is dealt as another evidence for a mental image.

There are still visual problems that we cannot resolve picturally. Suppose to have a sheet of paper, how thick is it after being folded once? how think is it after two foldings? And now, how thick is it when it is folded 50 times? Our image of that paper let us underestimate the total result.

We use not only language and visual imageries but also smell, sounds, and sense according to the input. A melody could never be represented in language or an image. Those different kinds of representation enriches our cognitive actions and often, we understand faster and more clear with the aid of diagrams or drawings. But mainly we express our thoughts - especially abstract ideas - in language.

6.1.2.2 Cognitive Maps

As already mentioned in section 5.3.2 we represent images and geographic items in cognitive maps. If we have to answer questions like 'What is the best route from our home to our work?', 'What way can we go if this optimal way is blocked?', 'Which city is more in the north: New York or Shanghai?', or 'Which countries flows the Mekong through?' then we must access our cognitive maps that represent our spatial environment. Orientation, path finding - or more general geographic problems - and even walking in darkness depend on the existence of such maps in your memory. (Hart & Moore, 1973; Thorndyke & Hayes-Roth, 1987), Yet, a computer algorithm would solve such geometric problem in a different - for us unusual - way. If a computer looks for a closest pair it might use a geometric algorithm that ascertain it deterministically by using a sweep line (Hinrichs, Nievergelt, & Schorn, 1988). For us, such a mechanical way were too unhandy (see below: Algorithm and Heuristics in 6.2.2)

6.2 Problem Solving

In our daily life we meet problems that need to be solved. Here, the problems are discussed are problems we can solve by goal-oriented and analytically thinking. Basically, a problem is a discrepancy between that what we know and that what we ought to know, or a situation that we are in and a situation that we suppose to be in. Problem solving is , therefore, to find a way to overcome those discrepancies. We are at the beginning at a starting point and have to go to the goal by allowed operations. In information technology a problem consists of a initial point, the allowed operations and the target state. These three components compose the problem space (Newell & Simon, 1972):

Suppose *PS* is the space of problem solving, *begin* is the initial state, *operation* the allowed and performed operation and *end* is the target state.

$$\text{PS(begin operation end): begin} \xrightarrow[\text{Operation}]{} \text{end}$$

The operation might be divided in multiple sub-operations and sub-targets:

$$\text{PS(begin operation end): begin} \xrightarrow[\text{Sub-Operation}]{} \text{sub-target} \xrightarrow[\text{Sub-Operation}]{} \text{sub-target} \xrightarrow[\text{Sub-Operation}]{} \text{end}$$

6.2.1 Well- / Ill- structured Problems

While we face problems we come across well-structured and ill-structured problems (Simon, 1973).

A well-structures problem has a clear ans precise defined initial state, clear defined operations and a distinct target state. Sometimes, there are more than one way to change the state (Anderson, 1988). In a ill-structured problem either one of them is not clear defined or even ambiguous, or two, or all of them, so that the problem is based on uncertainties. Therefore, the solution of the problem is very likely wrong or unsure.

If the way is long and difficult to solve the problem then we might use sub-operations to approach a sub-ordinate target - or in other words - we achieve our goal step by step. Two important tools are very helpful to understand and to find a way out: analysis and synthesis. Analysis mean that we break down the complexity to smaller parts and make it more easy to handle. Synthesis is the complementary process: We join the pieces together to a complex one. Naturally, the analysis takes place in the very beginning and the synthesis at the very end.

An example for a well-structured problem is any mathematical problem like: "What is 567,643 divided by 456?" The initial point is clear defined (the numbers are distinct), the target state is clear (the result) and the operations as well (dividing).

An example for a ill-structured problem is (Gardner, 1978; Weisberg, 1995): "The Schneeville Wolverines won the championship basketball game 72:49, yet not one man on the team scored match as a single point. How is that possible?"

6.2.2 Algorithm and Heuristics

So far the problem space is illustrated. We know now what a problem is, but we still don't know how to solve it. How do we find the way to the goal? There are two different strategies we can apply to the problem: algorithm or heuristic.

6.2.2.1 Algorithm

An algorithm is a methodical procedure composed of single subsequent steps that leads guaranteed to a solution (If the problem has a solution). It has the following properties (Six, 1999):

- The complete procedure must be described in an finite text. The elementary components are called steps.
- Each step must be performable.
- The procedure must end after finite steps.
- Each step is strong prescribed at any time. No coincidence is allowed (deterministic).

Here is given an example: Suppose, we must calculate the factorial of a number (n!). One algorithm could look like this:

```
1) Set a counter to 0 and a result variable to 1
2) Increase the counter by 1
3) Multiply the counter by the result variable and save  the result in the
   result variable.
4) Go back to step 2) until the counter is equal or bigger than n
5) The result is stored in the result variable
```

An algorithm looks inflexible and stiff but find the solution always. However, some algorithm are very time-consuming. One example is the famous traveling-salesman-problem. A salesman wants to visit all locations once as a round-trip and wants to return to the start position. He wants to find out what is the best route. Thus, this problem is a geographic problem. The algorithm has to check all possible routes and decide at the end which is the ideal. This is so time consuming that it takes the permutation of n locations (O(n!)). This problem is NP-hard and even NP-complete (Gary & Johnson, 1979). It would take years to find a route if n is bigger.

6.2.2.2 Heuristics

Practically, such a algorithm is not usable. Therefore, an informal and shorter way is searched for. We use heuristics to make the way of problem solving shorter. Heuristics are not exactly defined ways like algorithms. They are rules of thumb. Even coincidence is allowed. Thus, they are shorter and not deterministic, but a big disadvantage is that they not necessarily find a solution. And if they find a solution it might not be exactly, it's just a approximation. We have to accept such a unsure solution if the costs for an algorithm are too high.

We human beings use often heuristics because it is not our nature to think so strict and deterministic.

6.2.2.2.1 Problems with Heuristics

A heuristic is a subjective rule of thumb that might lead to a solution. However, there are some traps that prevent us to find a solution. The heuristic itself is not wrong but we apply the heuristic in a wrong way.

Functional Fixedness

Often we trust our experience and memory and look for similar ways to solve a problem that helped in the past. But such an analogy might even prevent us from finding the right way because the set of possible ways is limited to the already-known ways - the range is shorter.

We see an object only in that way how we use it daily but not necessarily in other - unusual - ways.

A matchbox is not only a container for matches. We could use it even as pedestal (Duncker, 1945) or a hammer is not only a tool to drive a nail into the wall but could also be used as end of a pendulum (Maier, 1930; 1931; Birch & Rabinowitz, 1951).

Cognitive Set

Such a fixation does not refer to the item itself but also to the use of operations or combinations of operations. Based on our experience we prefer certain operations more than unusual operations. Luchins and Luchins (1959) proved that in the nice water-pitcher problem. We tend to solve each problem in the same way and this way is not always the best, sometimes even unsolvable in the former ways.

People who apply for a job are often tested during an interview whether they are fixed thinking or not. In one example the candidate was lead into an empty room. Just a burning lamb was inside but no switch. He was asked to turn the light off. One solution were to rotate the bulb, but it was hot. One candidate took his shoe and throw it toward the bulb in order to destroy it. This candidate got the job. He was the only one who used his shoes in a different way but not as the usual function.

Perceptual Set

Before we start to solve a problem, we observe and view the problem from a point of view in order to understand what the problem is. Often, he doesn't change this point of view later but another point of view might be better. We perceive or encode the problem just from one side - may be another or even the opponent side might be lead to a quicker and more smarter solution. This obstacle is called perceptual set.

Moreover, these sets or hindrances influence each other and the definitions are not so strict. The perceptual set could also be defined as functional fixedness, namely, when we 'perceive' an object only as an object having one function. Or it could be a cognitive set because we see only the well-used function. The borders are flowing, but they are distinct to emphasize the kind of obstacle.

6.2.2.3 What is better ??

For our daily use one question arises now: Should I take an algorithm or shall I take a heuristic? For simple math problems it s quite clear: we use algorithm. But often, algorithm are very time-consuming because they are complex. On the other side is a heuristic not exact and might even not lead us to a solution. We must balance out the pro and cons and decide whether we can accept a longer time to find the result (algorithm) or whether we can accept an unreliable result. While using a heuristic ,often it helps to stay again from the problem and start the next day again. Probably we approach the problem different and find the solution sooner. Especially ill-defined problems causes the phenomenon that we find the solution suddenly after almost giving up. This phenomenon is called incubation. Such incubations occur quite often (Koestler, 1964)

6.3 Reasoning

We often must arrive at a conclusion in daily life. Thus, have several facts that need to be combined to a convenient result. In order to archive such a conclusion we may apply only logical operations. Such operations are always very abstract. Reasoning is very similar to logical operations that computer do.

6.3.1 Deductive Reasoning

The first kind of reasoning is the deductive reasoning. There are more than one fact, called premises, that let follow a logical correct conclusion. Always, there are used quantifiers: 'None', 'one', 'some', 'all'. Suppose *A, B* are true premises, then it the following conclusion *C* true as well.

All A are B
<u>All B are C</u>

All A are C

Every individual accepts this conclusion. But we often accept the following conclusion as well:

No A are B
<u>All B are C</u>

No A are C

People quickly accept such a conclusion, even though it is not true. It happens if in the premises occur the same quantifiers like in the conclusion. They provide a more 'comfortable' atmosphere. The appropriate term is atmosphere hypothesis (Woodworth & Sells, 1935).

Another way that people often take is that they simplify improperly the premises. Such a sentence like "All B are C" is regarded as "B = C". But indeed, there still might be some elements in C that are not B ("All B are C" means "B is smaller or equal C"). Such simplifications lead to wrong conclusions, of course.

In order to make sure that someone does not fall into such a trap one tool is very useful: venn diagrams. They can show visually the logic membership of elements to sets. In the latter case the venn diagram would look like this:

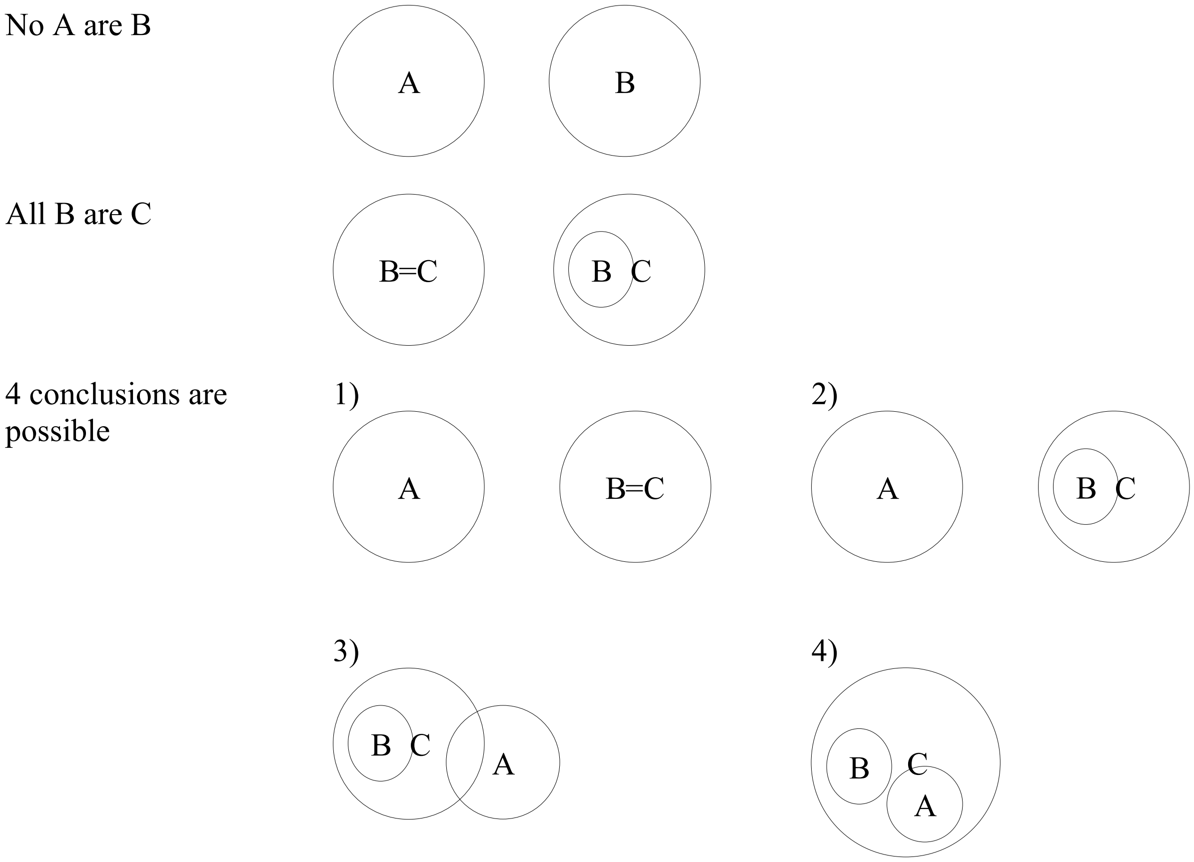

Fig. 9: Venn Diagram

Again, people take heuristics because no one take the effort and try every possible and allowed combination in order to find all conclusions.

6.3.2 Inductive Reasoning

Inductive reasoning leads not to a strictly logic conclusion but to a probably right conclusion. The experience of the former conclusions or empiric values form the conclusion. The conclusion might be wrong because some conditions might change that the conclusions base on. Some examples are:

- The sun has risen in the east every morning up so far. => The sun will also rise in the east tomorrow.
- All observed dogs are black. => All dogs are black.

One classical experiment performed Wason (1960). He told subjects several number combinations and asked them to find out a rule how the combinations are build (= constructing the next combination based on the former combinations). As soon as they were sure to find the rule they were to tell it. Sometimes it were better to observe the negative examples, but human beings seem to have big problems to investigate them.

Seldom, we compute probabilities mathematically correct. Suppose we play the heads-or-tails game, throw the coin and it shows after 6 times the heads, we usually think that the next try must be the tails. 'I had now six times the heads => The next time it is a tails'. From the mathematical point of view this conclusion is completely rubbish. The probability is still p = 0.5 per event, thus after 6 time: 0,016 - even after 100 times a heads it does not change (Kahnemann & Tversky, 1972). This kind of phenomenon is called the Monte Carlo Effect (Lück, 2002), because in the casino game the player often thinks in the same way: after several red throws the bullet must land in a black field. But the problem is that the bullet does not memorize the last fields.

6.4 Decision Making

(Serious) decision making is a process that includes sometimes problem solving and mostly reasoning. Reasoning we use for the analytical process first. When we have found a conclusion we can interlace that conclusion and come to a decision. Therefore, problem solving, reasoning, and decision making belongs together somehow. The last of the three is introduced here now.

Like problem solving, decision making comes across daily. In everyday life we must decide less important and more important things. But unfortunately, we don't come always to an optimal decision. More often, we base our decisions on our personality than on neutral facts, on biases and on - heuristics. That means, if we regard a decision like a problem that has to be solved, we use heuristics in order to find the best way.

6.4.1 Limits

Simon (1957) noted that our thinking is rational but limited by certain phenomenon. The term for that limitation is bounded rationality. The most common limit is satisficing.

6.4.1.1 Satisficing

Often, a problem or a decision making has not only several but many possibilities. If satisficing occurs we do not consider all possibilities but stop at the first possibility that seems to be good enough and drop the still left ones. All our requirements are fulfilled (otherwise we wouldn't stop here) there still might one possibility that is even better, though. Someone can only find the optimal solution if he considers really all possibilities with the same emphasis.

But often such an accurate analysis is not possible for several reasons:

- All possibilities do not occur at the same time (e.g. the choice of a marriage partner) so a real good decision making would take an endless time and the first possibilities were already invalid.

- Even if all ways were accessible at the same time it would take so much time to detect any detail. But often, we must decide very quickly. Therefore, there is a lack of information that lead to (conscious) uncertainty, but we must come to an end. Thus, we decide what seems to be the first yet best fitting possibility.

6.4.1.2 Elimination by Aspects

If we indeed see all options but are well knowing that we don't have time for such a detailed analysis we eliminate some aspects by minimizing a criterion for that aspect. Second, another aspect is chosen, a minimum criterion is created and those options that do not fulfill it are weeded out again. These elimination steps might be continued until one option remains. The limitation here is that we focus on one criterion but dismiss other factors that might as important as the criterion. They are wiped away unconsciously sometimes and the result is inexact.

But in practice we don't go until the very last possibility, we eliminate until some options are left and then we look more careful for an option (Payne, 1976).

6.4.2 Heuristics

Even for a decision making we use mental shortcuts that make it easier. As already mentioned above, heuristics are not so exact and don't guarantee the right solution. Furthermore, sometimes they even distort rational decisions.

6.4.2.1 Availability

According to Tversky & Kahnemann (1973) people judge depending on which information is more easy to access. Facts that occur more often or - more exactly - that we perceive more frequent are more available in our mind. The perception is influenced by how often it is presented, how unusual, how distinctive, and how outstanding it is. The decision making is based on this easy availability.

6.4.2.2 Representativeness

Some facts or situations have a similar appearance. We assume a communality between those facts and decide likewise because the second fact represents the first fact. Each situation or fact occur also with a certain probability. But this probability is not included in the calculation. Thus, the result can neglect relevant base rates (Tversky & Kahnemann, 1973).

6.4.2.3 Overconfidence

Occasionally, we have too much self-confidence and overestimate our own judgment. For example, people were given 200 question with two choices. They were to choose the right answer and to write down how likely their answer is correct. The result proved that people is highly overconfident. When someone was 100% confident, the rate was only 80%. (Fischhoff, Slovic, & Lichtenstein, 1977).

Chapter Summary

As first topic a classification of the stored information is introduced. It helps us to retrieve old and classify new information. Then, some types f non-language thinking are presented: imagery and cognitive maps are used according to the represented object. Is does not make sense - if even not impossible - to represent such an information in a verbal code. As first main part is problem solving illustrated. Problems are divided into ill- and well-defined problems. Here come algorithm and heuristics into play. Some raising problems with heuristics are mentioned. While we use a heuristic we are limited due to human properties. Second, reasoning is illustrated. There are two kind of reasoning explained: deductive and inductive reasoning. The third part consists of decision making. Again, here are some heuristics introduced.

In general, heuristic occur through all types of cognitive tasks. They are useful and often the result is right. We cannot deny such heuristics at all but must be aware of the inexact result. It is just a rule of thumb, the result might be right but is it not guaranteed. Only algorithms let us be sure to have a right answer but they are often not handy for the daily use. Thus, the use of a heuristic is a good alternative if a inexact result is tolerable.

7 Language

Language is - like any other code- a medium to transport and archive information. The code is arbitrary. The sender and recipient understand it. Language is a complex structure that consists of several levels but also the transportation of the language has multiple levels. Such levels are mentioned superficially here, the question here is how we learn and comprehend a language, that is how we employ our cognitive abilities in order to transport and recognize information.

7.1 General Properties of Languages

Pure information is code less. But pure information no one can process. When information is transferred, received or sent a code must be applied. Such a code is either an agreement specialized for machines, like computer, or a human understandable language. The code must be understandable by the sender and the recipient and the form of transportation must be reliable and adequate. Again, for each part there are multiple levels. The levels for language are introduced later.

Here, just one example for the transportation and storage is given. If information is transferred or stored we need a data medium. One simple example is here the paper and the ink. On the paper are written letters. Such letters are already a code and this code is already arbitrary. They must not necessarily be roman letters.

They even must not be human readable letters. A letter could also be a magnetic or optical sequence (like on a hard drive or a CD). In general, a code is predefined and the data medium must be changeable while receiving the information and then keep it durable until the information has arrived or is no longer needed.

For the human language we can use acoustic or written words as transportation, for storage we can use only written words, and as a data medium we have the air, paper or a screen and human receivable letters and words at our disposal.

But for a transfer of information there must be a sender and a receiver. We receive a language by ear or eye in an acoustic or optical form and understand it. This ability is called verbal comprehension. If we send out words, paragraphs and sentences then we are producing a language. This counterpart is called verbal fluency.

Psycholinguists (Brown, 1965; Clark & Clark, 1977; Glucksberg & Danks, 1975) have figured out that all languages have the following six properties. A human language has even more properties than a merely technical code:

1. Communicative: A language allows us to communicate between each other (= Transfer)

2. Arbitrary: A language is not necessarily based on logic. It is a predefined code
3. Productive: A language is based on rules yet own combinations of words can be produced
4. Dynamic: A language changes constantly
5. Meaningfully structured: A language has a structure. Not all combinations are meaningful but different arrangements create different meanings.
6. Multiple level: A language consists of several levels.

The first levels are the *phonemes*. We can produce by our mouth around 100 phones but each language use only a subset. Those phones consists of vowels and consonants. If we combine one or more phonemes then we build *words*. Of course, not all combinations are used. Only a predefined subset is allowed. Again, if we put words together according to arbitrary rules then we can construct well-structured *sentences*. It implies that not all combinations are allowed. These rules are based on a structure, the *syntax*. If such a sentence is understandable then we have encoded our information successful and is has a volitional meaning, the *semantic*.

7.2 Acquiring Language

The acquire of a language is a cognitive wonder. No baby learns a language by memorizing endless vocabulary lists and studying grammar rules. He just learn a language by listening. Already an unborn baby is sensitive for sounds from the environment and after birth he can response to the mother's voice immediately after birth (DeCasper & Fifer, 1980; DeCasper & Spence, 1986). They move rhythmically according to the speech (Field, 1978; Martin, 1981; Schaffer, 1977; Snow, 1977; Stern, 1977). For language investigations, not the facial expressions are important but the sounds besides crying. Interestingly, until four month all infants coo in all possible phones around the worlds, no matter which country they come from or which language the parents speak, even deaf children coo in the same way (Stoel-Gammon & Otomo, 1986). As they pass to the babbling age, deafs show no progress but normal infants slowly adapt the phones of the own language and loose the ability to sound foreign phones. This proves that the infants perceive, store and process cognitively language sounds from next people. Until by age 18 month, children own a vocabulary of up to 100 words (Siegler, 1991) depending on their cognitive capabilities (Menn & Stoel-Gammon, 2001). They produce two-syllable-words, then build one-word or two-words sentences, but never three-word sentences (Zimbardo, 1995). Rather, the sentences are getting longer. There are three semantic realms that occur at that age among all languages: the mover, movable items and localizations (Braine, 1976). The children are concerned with their own visible environment. By age around 2.5 years the children use words that refer to their feelings and wishes, they enhanced their treasury of words with mental describing words (Shatz, Wellman, & Silber, 1983).

Beside all these visible progresses it is still not known how they acquire the mother language. The grammar is not learned just by imitation. Children do not just parrot parent's words and sentences (Szagun, 1980). Yet, they learn new grammar rules (Lenneberg, 1962) and are constantly concerning with analyzing structures and synthesizing new sentences (Moskowitz, 1978; Carey, 1978). The corrections from the parents are rather referring to the validity than to the correct grammar (Brown & Hanlon, 1970).

But the social interaction is very important. A child cannot learn a language just by listening to TV or radio. He must interact with living persons (Moskowitz, 1978).

By age 10, a child's skill is basically as well developed as an adult, the sentences are just getting new words and more complexity.

If a child grows up in an environment of more than one language some other interesting questions arise because they use different lexicons and different pattern of syntax. The language is embedded in the local environment, thus a bilingual grown child is embedded in different cultures and environment. Many linguists believe that bilingual speakers have differing cognitive systems and furthermore, that a language influences the thinking. Thus, such bilinguals seem to think different when using the first or using the second one. But the question is still unclear answered.

Another fact is quite clear: the later we start learning a language the lesser we attain the level of native speakers. Children who started learning a second language until the age of 7 talked later as well as native speakers. With increasing age the skill declined rapidly and continuously (Johnson & Newport, 1989; Bialystock & Hakuta, 1999; Hakuta, 2001). It seems that during the early childhood there is a sensitive period for acquiring a language or even for acquiring multiple languages at the same time.

7.3 Comprehension

If someone want to say something to us he uses a language. His goal of the sender is that the receiver understand as end-product our proposition. While we process the input - as voice or as written word - we execute several levels until we really understand the intention or proposition of what the sender is saying to us. This is independent on how we receive the message.

After receiving and perceiving the message we recognize the words or word strings. Now we must convert them into a set of propositions. It is not enough just to identify the meaning of the words, it is not just a word for word translation, other important informations such as grammar and sequences in the sentence are needed as well in order to prevent ambiguity and misunderstandings.

7.3.1 Ambiguity and Expectation

Very often a word has different meanings. Not only this, sometimes a word consisting of the very same letters is used as noun or as verb. Thus, there are more than one options to use a word. Despite the several meanings we can comprehend a language pretty fast. We can listen (and understand) to up to 250 words per minute and college students can read around 280 words per minute, or more than four words per second. Even though most words of a sentence have multiple meanings we can understand quickly. Later, it is shown how can we do that at that speed. Here there are shown now some ambiguities:

- **Word**: One word has several meanings: e.g. *to consider* has at least 10 different meanings.
- **Word form**: a word can be a verb, an adjective or a noun: e.g. fat has two verb forms: noun or adjective, *haunt* can be a noun or a verb
- **Lexical**: The exact meaning is a word cannot be determined because the context is not given: *The teacher strikes idle kids*: strikes" can occur as either an verb meaning to hit or a noun meaning a refusal to work. Meantime, "idle" can occur as either an verb or an adjective.
- **Syntax**: Exactly the same sentence structure has two meanings: *visiting relatives can be a nuisance*. The first meaning is that relatives bother us and the second is the we don't like to visit them.

No language has no ambiguity. Linguists know this problem for a long time. But also computer programmer who are writing a language program meet this problem. It is not simple to determinate whether a word is a verb or not. The simplest way to check all possibilities is to check all of them but suppose a sentence with 5 ambiguous words let the speed bog down drastically. Obviously, it is not a problem for us to dissolve quickly such ambiguities. Now, the question arise how we can handle such a rich amount of options in such a short time.

Language comprehension seems to be just a bottom-up process. We receive the message and process level-by-level until we understand the meaning. Each word is checked concerning the possible meanings and the syntax is identified. Word set are grouped to grammatical categories and as last level the proposition is found.

But we use top-down processes as well. A top-down process is controlled by the expectations of how a sentence could continue before we have received the rest of the sentence. Therefore, we guess what follows the already received first part of a sentence while the sentence is still being spoken. This implies, of course, that we have already processed the first part as bottom-up process, otherwise we could not guess the following part by the meaning. Indeed, the top-down process accelerate the comprehension considerably. Even programmer use this technique to shorten the run time of such programs.

7.3.2 Lexical Lookup, Syntactic and Semantic Processing

For each level we have to process the incoming messages. As the decoding is a bottom-up process, we process the lexical level first, then the syntactic and at least the semantic level in order to attain full comprehension. But we cannot divide the two latter ones sharply. To recognize the semantic we need to involve the syntax as well.

7.3.2.1 Lexical and Syntactic Processing

As we grow up, we build our own dictionary. Each word has an entry there. It contains the sound of the word, the spelling, and the meanings of each word. If one word is recognized and processed the corresponding entry is activated and all meanings are scanned through. If a word has more than one meanings all entries are accessed accordingly. The more meanings a word has the more entries are accessed. This happens unconscious, even if we are not aware that a word is ambiguous. Swinney (1979) found out that the activation of all meanings does not depend on the context and therefore, they are pure bottom-up processes. This touching of all entries lasts a very short time.

But a simple lexical lookup is not sufficient to understand an underlying meaning. Furthermore, the sentence must me parsed as well. A mere lexical lookup does not detect any sequences that are even more important to acquire the intended meaning. Some experiments let us believe that a subject very likely split a sentence into parts (Fodor & Bever, 1965; Garrett, Bever, & Fodor, 1966).

7.3.2.2 Syntactic and Semantic Heuristics

In order to dissolve the semantic information we are supposed to use a systematic approach - an algorithm. The problem is that the amount of possible combinations of a structure of a sentences is endless. But there is no algorithm that is able to process infinite combinations. There might also be a structure that is unaccounted within the algorithm. Again, we seem to use heuristics - rules of dumb - that shorten the finding of the meaning, or even make it possible to find them. Some of them are:

- **Word Order Strategy**: If there is the sequence Noun-Verb-Noun then the first word is supposed to be a noun that is the actor who does what is described by the second word, the verb. The second noun is supposed to be the object of that action. However, this strategy does only fit to simple and active sentences. Thus, if there is a passive sentence this strategy must be rewritten. First of all, therefore, must be decided before applying the strategy whether there is a passive or a active sentence.

- **Cue word strategy**: After a relative pronoun begins a new clause. However, if the pronoun is omitted this strategy fails. Often, 'that' is omitted. In this case this strategy does not divide a sentence in its parts.
- **Semantic strategy**: According to the verb there is a certain action or case expected. Each verb let expect a particular group or given thing as object. E.g., the verb 'go' gets us to expect a location as object or 'paint' a visible solid item. This strategy targets at the semantic and is useful to anticipate the following rest of the sentence.

Chapter summary

This chapter deals with human language. First, it is generalized to a code to transport or store information. Second, the amazing step of acquiring a language is explained more deeply. The next step is to explain how we use language in daily life - from the internal point of view: how do we comprehend a spoken or written word. Several levels are illustrated. such as lexical lookup, syntactic and semantic processing. Again, here are some heuristics listed.

8 Intelligence

The last chapter of this thesis deals with intelligence. It is already difficult how to define intelligence. There are even controversial approaches. A very general definition might be that intelligence is just the ability or capability to do such thing like mentioned above, that is problem solving, reasoning, decision making, archiving a mental goal, or acquiring a language. The definition is not only different from which point of view but additionally from the culture, or - in other words - from an external view because intelligence might not be understood isolated. Eastern cultures pay more attention to modesty rather than to self-portrayal. Thus, someone is more intelligent who does not show it. African people even see intelligence in a complete different way than western people. Such people would be not regarded as intelligent in western countries and vice versa because they have another emphasis that were on the other side unimportant. (Cole, Gay, Glick, & Sharp, 1971; Gladwin, 1970). This fact has influence to later mentioned methods of measuring intelligence.

Intelligence can be improved and reinforced during the life span. There is not a fixed and unchangeable amount of intelligence that we get at birth. (Dettermann & Sternberg, 1982; Perkins & Grotzer, 1997; Ramey, 1994; R. J. Sternberg, Okagaki, & Jackson, 1990) Furthermore, like we train and practice other skills, intelligence can be improved by daily practice in our daily tasks by thinking systematically and carefully. Already at school time a teacher can increase students' intelligence. (Ceci, 1996). If they are encouraged to use their brain in a productive way they got a higher capability to apply their intelligence (R. J. Sternberg, Torff, & Grigorenko, 1998).

8.1 Measuring

The intelligence can only be measured by tests and the scores are compared to other scores. It has always a reference to other subjects. There is no absolute gauge like kg or meter. But, in order to measure intelligence reliably such tests must have some characteristics:

- **Validity**: Such a test must be able to measure what intelligence really is, not other things. If a subject is asked to connect two adjacent points on a paper by a line it has nothing to do with intelligence. Each task or question is supposed to check what refers to intelligence.
- **Reliability**: The test must provide a reliable score independent on when and where it is held and who is tested. If someone is tested several times within a short time frame the score is supposed to be the same.
- **Standardization**: All subject ought to have the same conditions. This goal is not able to

archive completely because external circumstances cannot be excluded completely (How awake is the subject, how hot is the weather and so on, is there any dis quietness), but the conditions of the test can be equalized: the same length of the test, the same time, the same font of the text, the same and simple words, the same time of the day, etc.)

8.1.1 Intelligence Quotient

Very early the intelligence was measured by paying attention only to the real or chronological age. But this was far too inaccurate. Binet (1857-1911) introduced another aspect. He compared subject by their score of tests regardless how (chronological) old they are. If a 12-years-old boy has the same score like the average of the 14-years-old-children he has a mental age of 14. But this method is still not good enough because is is useless when chronological ages need to be compared. The next step was the beginning of a formula that is till today in use. The mental age is divided by the chronological age times 100:

$$IQ = \frac{mental\ age}{chronological\ age} \times 100$$

Thus, if the 12-years-old boy is a mental age of 14 he has an IQ of

$$IQ = \frac{14}{12} \times 100 = 117$$

The formula works well until an age of 16 because the intelligence increases yearly. After 16, the intelligence does not go up as much so that the difference between mental and chronological age decreases and the IQ suddenly goes to 100. Suppose, that boy with the age difference of 2 years is 30 then his IQ approximates 100:

$$IQ = \frac{32}{30} \times 100 = 107$$

Therefore, the base of the mental age is left. Now, the base is the huge number of tests that builds a normal distribution curve. Most of the people are around the middle whereas only very few are extremely intelligent or mentally retarded.

68 % of all people have a score of 85 - 115 and around 95% have an IQ of 70 to 130.

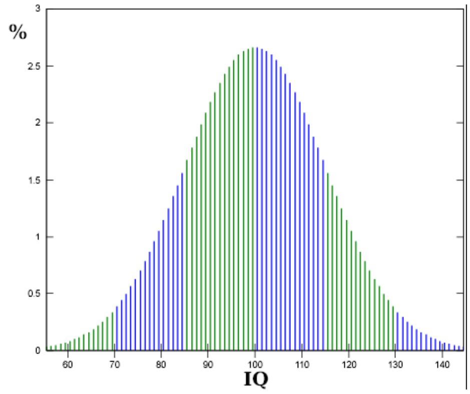

Fig. 10: Normal Distribution of IQ

8.1.2 Stanford-Binet Scale

There are several tests that help to determine someone's IQ. The Stanfort-Binet test was invented by Binet and Simon and was improved by Terman and Merril from the Standford University (hence the first name). This test measures the cognitive ability by asking some series of question like a scale. The more are answered the higher is the graded scale. The current version is number 5. The questions are about:

- **Verbal Reasoning**: *Vocabulary*: A given word has to be explained; *Comprehension*: A coherence within the daily life of a given fact is to be shown; *Absurdities*: There is one odd feature of a given situation. This has to be identified; *Relations*: Among four items one does not fit. The fourth has to be selected and explained why it does not fit.
- **Quantitative Reasoning**: *Number series*: There is a series of numbers, it has to be completed or continued; *Quantitative*: A simple arithmetical problem that is introduced as text has to be solved
- **Figural Reasoning**: A set of geometric pieces is shown. They have to be combined together to a demanded form
- **Short-term memory**: *Sentences*: A just received sentence has to be repeated; *Digits*: After listening to a series of digits, it must be repeated either forward or backward; *Objects*: A set of items is shown in a particular sequence. They have to be shown in the same sequence as before.

Each of these factors is tested in two separate domains, verbal and nonverbal, in order to accurately assess individuals with deafness, limited language skills, or communication disorders. The Stanford-Binet test is regarded as valid and high reliable. Therefore, it is widely used for years.

8.1.3 Wechsler Scale

This test was developed by David Wechsler and revised in 1995. It includes three tests, one for adults - the Wechsler Adult Intelligence Scale-Revised (WAIS-R), one for children - Wechsler Intelligence Scale for Children-3rd edition (WISC-III), and one for preschool children - Wechsler Preschool and Primary Scale of Intelligence (WPPSI).

The test provides three scores:

- **Verbal Scale**: *Information*: general knowledge acquired from culture and actual events; *Comprehension*: social questions has to be answered; *Arithmetic*: A simple arithmetical problem that is introduced as text has to be solved; *Similarities*: It has to be explained how two items or ideas are akin; *Vocabulary*: A word must be defined; *Digit span*: After listening to a series of digits, it must be repeated either forward or backward; *Letter-Number Sequencing*: a test of attention/concentration and short-term memory by ordering given mixed letters and digits.
- **Performance Scale**: *Picture Completion*: the ability of how quickly visual details are perceived is tested; *Digit Symbol*: de- and encoding; *Block Design*: Given block must be changed to a demanded pattern; *Matrix Reasoning*: a part from the problem solving and inductive reasoning realm; *Picture Completion*: Each given picture lacks one detail. The subject must find out what it is; *Symbol Search*: Hereby the speed of the visual perception is tested; *Object Assembly*: A set of geometric pieces is shown. They have to be combined together to a demanded form.
- **Overall Scale**: This scale is based on the combined scores as a composite.

The main difference between Stanford-Binet and Wechsler is that Stanford-Binet is based on the mental age and therefore only appropriate for children. Wechsler has a separate part for children and even for preschool children.

8.2 Types of Intelligence

8.2.1 Gardner's Theory

It is difficult to say what exactly intelligence is. Several approaches have been made. Gardner (1983, 1993, 1999) had the idea of a multiple theory. He regards intelligence as a system of eight intelligences. Each realm is distinct and independent but they can interact each other. Everybody has a different amount of each realm and thus everybody has an unique cognitive profile. If someone might be very intelligent in music he might not be good at languages. Thus, the balance over all realms result in the performance intelligence.

1. Linguistic intelligence: When someone has the ability to be good at languages then he has a high linguistic intelligence. They learn foreign languages very easily as they have high verbal memory and recall and an ability to understand and deploy syntax and structure. This intelligence also has it's realm in words, spoken or written. They are typically good at reading, writing, telling stories, and memorizing words and dates. They tend to learn best by reading, taking notes, and listening to lectures, and via discussion and debate. They are also frequently skilled at explaining, teaching, and oration or persuasive speaking. Those who have an high level at linguistic intelligence are mostly writers, lawyers, philosophers, politicians, and teachers.
2. Logical-mathematical intelligence: People who can and like to think logic, abstract have a high level at this type of intelligence. It includes inductive and deductive reasoning, and numbers. But it means not only mathematics, chess, computer programming, and other logical or numerical activities but also abstract pattern recognition, scientific thinking and investigation, and the ability to perform complex calculations. People who own a lot of such an intelligence are scientists, mathematicians, doctors, and economists.
3. Spatial intelligence: People with strong visual-spatial intelligence are typically very good at visualizing and mentally manipulating objects. They have a strong visual memory and are often artistically inclined. Those with visual-spatial intelligence also generally have a very good sense of direction. It has a high correlation between spatial and mathematical abilities if solving a mathematical problem involves visually manipulating symbols like vectors or geometry. And it has a strong correlation between bodily-kinesthetic intelligence if someone has a good hand-eye coordination but here more in a technical sense (someone can show his spatial idea with his hand or on paper). People with such an intelligence are artists, engineers, and architects.
4. Bodily-kinesthetic intelligence: If someone can control his body and his movements he has a strong bodily-kinesthetic intelligence. People are generally adept at physical activities such as sports or dance and often prefer activities which utilize movement. They may enjoy acting or performing, and in general they are good at building and making things. They often learn best by physically doing something rather than reading or hearing about it. Usually athletes, martial art sportsmen, dancers, actors, comedians, builders, and artisans are equipped with bodily-kinesthetic intelligence.
5. Musical intelligence: Those who have a high level of musical-rhythmic intelligence display a greater sensitivity to sounds, rhythms, tones, and music. They normally have good pitch, a

exact feeling for rhythm, and are able to sing, play musical instruments, and compose music. Typical jobs for high musical skills are musicians, singers, conductors, and composers.

6. Interpersonal intelligence: People in this category are usually extroverts, can easily interact with others and are characterized by their sensitivity to others' moods, feelings, temperaments, and motivations and their ability to cooperate in order to work as part of a group. They communicate effectively and empathize easily with others, and may be either leaders or followers. People like that make a career as politicians, managers, social workers, and diplomats.
7. Intrapersonal intelligence: This is just the opposite to interpersonal intelligence: People are introverted and prefer to work alone. They have introspective and self-reflective capacities. They are usually highly self-aware and capable of understanding their own emotions, goals, and motivations. They often have an affinity for thought-based pursuits such as philosophy. There is often a high level of perfectionism associated with this intelligence. Philosophers, psychologists, theologians, and writers have a high level at intrapersonal intelligence.
8. Naturalistic intelligence: Originally, Gardner developed just seven intelligences. This is the newest of the intelligences and is not as widely accepted as the original seven. It is important to note that this type of intelligence is not part of Gardner's original theory of Multiple Intelligences. People who have a greater sensitivity to nature and their place within it, the ability to nurture and grow things, and greater ease in caring for, taming, and interacting with animals have a high level at this intelligence. They are also good at recognizing and classifying different species. Thus, they are mostly scientists, naturalists, conservationists, gardeners, and farmers.

Gardner's theory in not accepted widely among psychologists. The most common criticisms argue that Gardner's theory is based on his own intuition rather than empirical data and that the intelligences are just other names for talents or personality types. Despite these criticisms, the theory has been accepted among educators over the past twenty years.

8.2.2 The Triarchic Theory

Steinberg prefers a triarchic theory of human intelligence (R.J. Sternberg, 1985). His emphasis laid on how the types of intelligences work together. The three main aspects are: analytical, creative, and practical. The analytical part is used while comparing, contrasting, or evaluating ideas. The creative part is used while create new ideas, new situations or invent new things. The last one - practical - is activated while someone can adapt to every day's demands and can apply new ideas in a practical way.

Again, here as before, a subject might be good at one part, what counts is the summary of all parts together. His intelligence performance consists of the total of all three parts.

Chapter Summary

In the current chapter it is shown how intelligence is measured. After mentioning which preconditions a valuable test must fulfill, some formulas are introduced, for example how the IQ is computed. Two main scales - Stanford-Binet and Wechlser - are presented. Then, there are two approaches illustrated of how intelligences might be as a system: Gartner's theory and the triarchic theory. All these - and much more- theories show that is it not easy, if not impossible, to well define what intelligence is. They are all just tries and approaches. But it is still very important to measure intelligence, either as prediction or to ascertain the actual state.

Conclusion

Even though all subbranches of cognitive psychology are still under investigation we already can say that wherever we look the processes are optimized and goal-oriented. One example is the use of cognitive maps. We encode and store the geographic map in such a way that we later are able to find the way out. This is sometimes even important for survival. This actual encoding and storing we still don't know, but we know that it is reliable and effective.

The process of automation allows us to do different things at the same time even though we are not able to do multiple things at the same time. But after getting automatic we are again free for new tasks. This system provides us a very flexible, individual and constructive way of learning more and more. Here comes to surface that attention and learning are working together. But also different parts of thoughts are able to work together. Often, we need problem solving as part of decision making and vice versa.

If there are more process involved they fit and work together via well defined 'interfaces'. Thus, the three parts of memory, sensory, short-term and long-term memory works well together. Or sensation and perception are a base for attention and conscious. It seems as if everything is planned and constructed in order to fulfill the cognitive tasks that need to be done for daily life.

But there are still limitations. We are not perfect. Thus, while using heuristics we are in danger of approximate our limitations. If we solve problems we experience limits like functional fixedness, cognitive sets or perceptual sets. On the other side, we are able to solve ill-defined problems. If we were just like a machine we never could do that. Feeding a computer with a ill-defined problem will lead to a crash or not solution. But we are still able to reorganize a ill-defined problem until it will be solved (if there is a solution). The only parameter that is more in need is time.

For the author the most interesting facts is that we as human beings use heuristics in very much realms of cognitive processes. Hereby, the processing if information resembles the processes of information processing in computer and roboter. Furthermore, it is interesting that the human brain does not use the most effective theoretical algorithm (see 4.3.2.3), but - on the other side - does not waste efficiency ,that is, our brain does not slow down processes unnecessary.

Cognitive psychology is a very fascinating and helpful branch for daily life. Really, in each part of our life cognitive psychology is involved. There is still al lot of investigate because the human brain is very complex and in transparent.

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Appendices

Table of figures