Cognitive Psychology and Cognitive Neuroscience/Reasoning and Decision Making

Introduction

No matter which public topic you discuss or which personal aspect you worry about – you need reasons for your opinion and argumentation. Moreover, the ability of reasoning is responsible for your cognitive features of decision making and choosing among alternatives.

Everyone of us uses these two abilities in everyday life to the utmost. Let us, therefore, consider the following scene of Knut's life:

"It is again a rainy afternoon in Osnabrück (Germany) and as Knut and his wife are tired of observing the black crows in their garden they decide to escape from the shabby weather and spend their holidays in Spain. Knut has never been to Spain before and is pretty excited. They will leave the next day, thus he is packing his bag. The crucial things first: some underwear, some socks, a pair of pyjamas and his wash bag with a toothbrush, shampoo, soap, sun milk and insect spray. But, Knut cannot find the insect spray until his wife tells him that she lost it and will buy some new. He advises her to take an umbrella for the way to the chemist as it is raining outside, before he turns back to his packing task. But what did he already pack into his bag? Immediately, he remembers and continues, packing his clothing into the bag, considering that each piece fits another one and finally his Ipod as he exclusively listens to music with this device. Since the two of them are going on summer holidays, Knut packs especially shorts and T-Shirts into his bag. After approximately half an hour, he is finally convinced that he has done everything necessary for having some fine holidays."

With regard to this sketch of Knut's holiday preparation, we will explain the basic principles of reasoning and decision making. In the following, it will be shown how much cognitive work is necessary for this fragment of everyday life. After presenting an insight into the topic, we will illustrate what kind of brain lesions lead to what kind of impairments of these two cognitive features.

Reasoning

In a process of reasoning available information is taken into account in form of premises. Through a process of inferencing a conclusion is reached on the base of these premises. The conclusion's content of information goes beyond the one of the premises. To make this clear consider the following consideration Knut makes before planning his holiday:

```
1. Premise: In all countries in southern Europe it is pretty warm during summer.
2. Premise: Spain is in southern Europe.
Conclusion: Therefore, in Spain it is pretty warm during summer.
```

The conclusion in this example follows directly from the premises but it entails information which is not explicitly stated in the premises. This is a rather typical feature of a process of reasoning. In the following it is decided between the two major kinds of reasoning, namely **inductive** and **deductive** which are often seen as the complement of one another.

Deductive reasoning

Deductive reasoning is concerned with syllogisms in which the conclusion follows logically from the premises. The following example about Knut makes this process clear:

```
1.Premise: Knut knows: If it is warm, one needs shorts and T-Shirts.
2.Premise: He also knows that it is warm in Spain during summer.
Conclusion: Therefore, Knut reasons that he needs shorts and T-Shirts in Spain.
```

In the given example it is obvious that the premises are about rather general information and the resulting conclusion is about a more special case which can be inferred from the two premises.

Hereafter it is differentiated between the two major kinds of syllogisms, namely categorical and conditional ones.

Categorical syllogisms

In categorical syllogisms the statements of the premises begin typically with “all”, “none” or “some” and the conclusion starts with “therefore” or “hence”. These kinds of syllogisms fulfill the task of describing a relationship between two categories. In the example given above in the introduction of deductive reasoning these categories are *Spain* and *the need for shorts and T-Shirts*. Two different approaches serve the study of categorical syllogisms which are the **normative approach** and the **descriptive approach**.

The normative approach

The normative approach is based on logic and deals with the problem of categorizing conclusions as either valid or invalid. “Valid” means that the conclusion follows logically from the premises whereas “invalid” means the contrary. Two basic principles and a method called **Euler Circles** (Figure 1) have been developed to help judging about the validity. The first principle was created by Aristotle and says “If the two premises are true, the conclusion of a valid syllogism must be true” (cp. Goldstein, 2005). The second principle describes that “The validity of a syllogism is determined only by its form, not its content.” These two principles explain why the following syllogism is (surprisingly) valid:

```
All flowers are animals. All animals can jump. Therefore, all flowers can jump.
```

Even though it is quite obvious that the first premise is not true and further that the conclusion is not true, the whole syllogism is still valid. Applying formal logic to the syllogism in the example, the conclusion is valid.

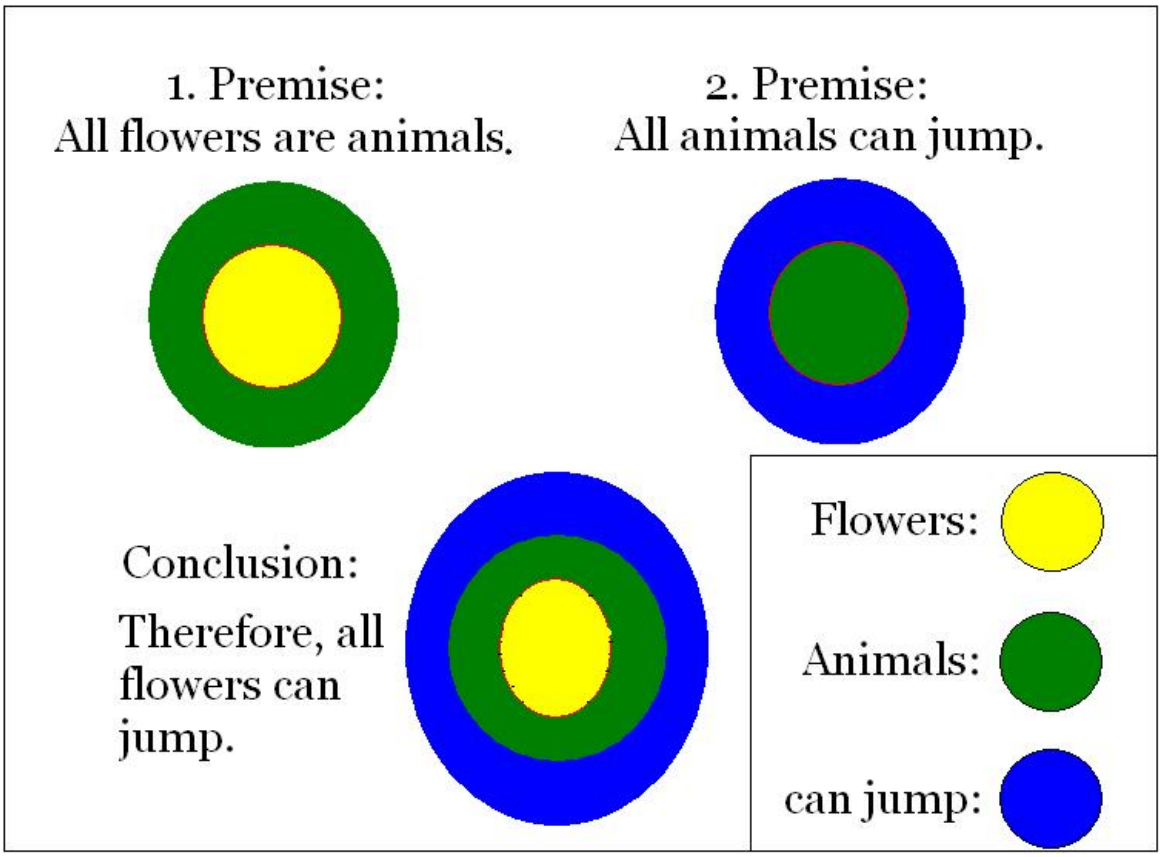

Figure 1, Euler Circles

Due to this precondition it is possible to display a syllogism formally with symbols or letters and explain its relationship graphically with the help of diagrams. There are various ways to demonstrate a premise graphically. Starting with a circle to represent the first premise and adding one or more circles for the second one (Figure 1), the crucial move is to compare the constructed diagrams with the conclusion. It should be clearly laid out whether the diagrams are contradictory or not. Agreeing with one another, the syllogism is valid. The displayed syllogism (Figure 1) is obviously valid. The conclusion shows that everything that can jump contains animals which again contains flowers. This agrees with the two premises which point out that flowers are animals and that these are able to jump. The method of Euler Circles is a good device to make syllogisms better conceivable.

The descriptive approach

The descriptive approach is concerned with estimating people´s ability of judging validity and explaining judging errors. This psychological approach uses two methods in order to determine people`s performance:

```
Method of evaluation: People are given two premises, a conclusion and the task to judge whether the syllogism is valid or not.
                      (preferred one)
Method of production: Participants are supplied with two premises and asked to develop a logically valid conclusion.
                      (if possible)
```

While using the **method of evaluation** researchers found typical misjudgments about syllogisms. Premises starting with “All”, “Some” or “No” imply a special atmosphere and influence a person in the process of decision making. One mistake often occurring is judging a syllogism incorrectly as valid, in which the two premises as well as the conclusion starts with “All”. The influence of the provided atmosphere leads to the right decision at most times, but is definitely not reliable and guides the person to a rash decision. This phenomenon is called the **atmosphere effect**.

In addition to the form of a syllogism, the content is likely to influence a person's decision as well and causes the person to neglect his logical thinking. The belief bias states that people tend to judge syllogisms with believable

conclusions as valid, while they tend to judge syllogisms with unbelievable conclusions as invalid. Given a conclusion as like "Some bananas are pink", hardly any participants would judge the syllogism as valid, even though it might be valid according to its premises (e.g. Some bananas are fruits. All fruits are pink.)

Mental models of deductive reasoning

It is still not possible to consider what mental processes might occur when people are trying to determine whether a syllogism is valid. After researchers observed that Euler Circles can be used to determine the validity of a syllogism, Phillip Johnson–Laird (1999) wondered whether people would use such circles naturally without any instruction how to use them. At the same time he found out that they do not work for some more complex syllogisms and that a problem can be solved by applying logical rules, but most people solve them by imagining the situation. This is the basic idea of people using mental models – a specific situation that is represented in a person's mind that can be used to help determine the validity of syllogisms – to solve deductive reasoning problems. The basic principle behind the Mental Model Theory is: A conclusion is valid only if it cannot be refuted by any mode of the premises. This theory is rather popular because it makes predictions that can be tested and because it can be applied without any knowledge about rules of logic. But there are still problems facing researchers when trying to determine how people reason about syllogisms. These problems include the fact that a variety of different strategies are used by people in reasoning and that some people are better in solving syllogisms than others.

Effects of culture on deductive reasoning

People can be influenced by the content of syllogisms rather than by focusing on logic when judging their validity. Psychologists have wondered whether people are influenced by their cultures when judging. Therefore they have done cross–cultural experiments in which reasoning problems were presented to people of different cultures. They observed that people from different cultures judge differently to these problems. People use evidence from their own experience (empirical evidence) and ignore evidence presented in the syllogism (theoretical evidence).

Conditional syllogisms

Another type of syllogisms is called "conditional syllogism". Just like the categorical one, it also has two premises and a conclusion. In difference the first premise has the form "If … then". Syllogisms like this one are common in everyday life. Consider the following example from the story about Knut:

```
1. Premise: If it is raining, Knut`s wife gets wet.
2. Premise: It is raining.
Conclusion: Therefore, Knut`s wife gets wet.
```

Conditional syllogisms are typically given in the abstract form: "If p then q", where "p" is called the **antecedent** and "q" the **consequent**.

Forms of conditional syllogisms

There are four major forms of conditional syllogisms, namely **Modus Ponens**, **Modus Tollens**, **Denying The Antecedent** and **Affirming The Consequent**. These are illustrated in the table below (Figure 2) by means of the conditional syllogism above (i.e. If it is raining, Knut`s wife gets wet). The table indicates the premises, the resulting conclusions and it shows whether these are valid or not. The lowermost row displays the relative number of correct judgements people make about the validity of the conclusions.

Obviously, the validity of the syllogisms with valid conclusions is easier to judge in a correct manner than the validity of the ones with invalid conclusions. The conclusion in the instance of the modus ponens is apparently valid. In the example it is very clear that Knut`s wife gets wet, if it is raning.

	MODUS PONENS	MODUS TOLLENS	DENYING THE ANTECEDENT	AFFIRMING THE CONSEQUENT
DESCRIPTION	The antecedent of the first premise is affirmed in the second premise.	The consequent of the first premise is negated in the the second premise.	The antecedent of the first premise is negated in the second premise.	The consequent of the first premise is affirmed in the second premise.
1. PREMISE	If it is raining, Knut`s wife gets wet.	If it is raining, Knut`s wife gets wet.	If it is raining, Knut`s wife gets wet.	If it is raining, Knut`s wife gets wet.
2. PREMISE	It is raining.	Knut`s wife does not get wet.	It is not raining.	Knut`s wife gets wet.
CONCLUSION	Therefore, Knut`s wife gets wet.	Therefore, it is not raining.	Therefore, Knut`s wife does not get wet.	Therefore, it is raining.
VALIDITY	✓	✓	✗	✗
CORRECT JUDGMENTS	97%	60%	40%	40%

Figure 2, Different kinds of conditional syllogisms

The validity of the modus tollens is more difficult to recognize. Referring to the example, in the case that Knut`s wife does not get wet it can`t be raining. Because the first premise says that if it is raining, she gets wet. So the reason for Knut`s wife not getting wet is that it is not raining. Consequently, the conclusion is valid.

The validity of the remaining two kinds of conditional syllogisms is judged correctly only by 40% of people. If the method of denying the antecedent is applied, the second premise says that it is not raining. But from this fact it follows not logically that Knut`s wife does not get wet – obviously rain is not the only reason for her to get wet. It could also be the case that the sun is shining and Knut tests his new water pistol and makes her wet. So, this kind of conditional syllogism does not lead to a valid conclusion.

Affirming the consequent in the case of the given example means that the second premise says that Knut`s wife gets wet. But again the reason for this can be circumstances apart from rain. So, it follows not logically that it is raining. In consequence, the conclusion of this syllogism is invalid.

The four kinds of syllogisms have shown that it is not always easy to make correct judgments concerning the validity of the conclusions. The following passages will deal with other errors people make during the process of conditional reasoning.

The Wason Selection Task

The Wason Selection Task [1] is a famous experiment which shows that people make more errors in the process of reasoning, if it is concerned with abstract items than if it involves real-world items (Wason, 1966).

In the abstract version of the Wason Selection Task four cards are shown to the participants with each a letter on one side and a number on the other (Figure 3, yellow cards). The task is to indicate the minimum number of cards that have to be turned over to test whether the following rule is observed: “If there is a vowel on one side then there is an even number on the other side”. 53% of participants selected the ‘E’ card which is correct, because turning this card over is necessary for testing the truth of the rule. However still another card needs to be turned over. 64 % indicated that the ‘4’ card has to be turned over which is not right. Only 4% of participants answered correctly that the ‘7’ card needs to be turned over in addition to the ‘E’. The correctness of turning over these two cards becomes more obvious if the same task is stated in terms of real-world items instead of vowels and numbers. One of the experiments for determining this was the beer/drinking-age problem used by Richard Griggs and James Cox (1982). This experiment is identical to the Wason Selection Task except that instead of numbers and letters on the cards everyday terms (beer, soda and ages) were used (Figure 3, green cards). Griggs and Cox gave the following rule to the participants: “If a person is drinking beer then he or she must be older than 19 years.” In this case 73% of participants answered in a correct way, namely that the cards with “Beer” and “14 years” on it have to be turned over to test whether the rule is kept.

Why is the performance better in the case of real–world items?

There are two different approaches which explain why participants' performance is significantly better in the case of the beer/drinking-age problem than in the abstract version of the Wason Selection Task, namely one approach concerning permission schemas and an evolutionary approach.

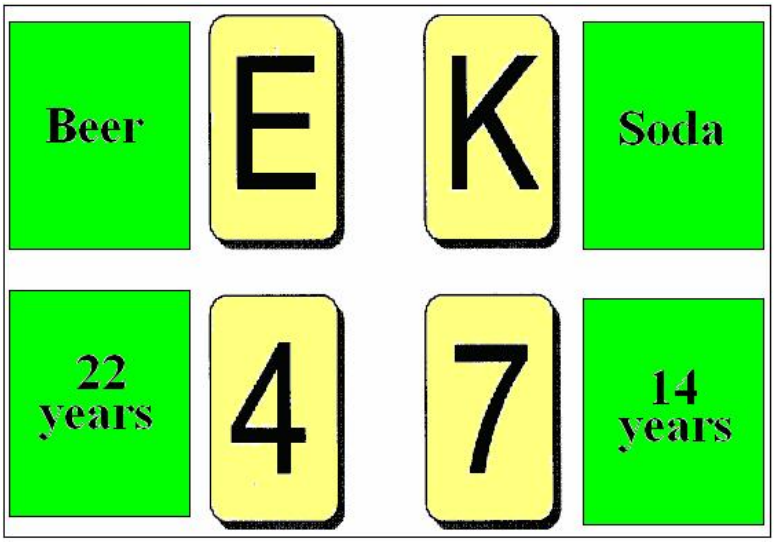

Figure 3, The Wason Selection Task

The regulation: "If one is 19 years or older then he/she is allowed to drink alcohol", is known by everyone as an experience from everyday life (also called **permission schema**). As this permission schema is already learned by the participants it can be applied to the Wason Selection Task for real–world items to improve participants` performance. On the contrary such a permission schema from everyday life does not exist for the abstract version of the Wason Selection Task.

The evolutionary approach concerns the important human ability of **cheater-detection** . This approach states that an important aspect of human behaviour especially in the past was/is the ability for two persons to cooperate in a way that is beneficial for both of them. As long as each person receives a benefit for whatever he/she does in favour of the other one, everything works well in their social exchange. But if someone cheats and receives benefit from others without giving it back, some problem arises (see also chapter 3. Evolutionary Perspective on Social Cognitions [2]). It is assumed that the property to detect cheaters has become a part of human`s cognitive makeup during evolution. This cognitive ability improves the performance in the beer/drinking-age version of the Wason Selection Task as it allows people to detect a cheating person who does not behave according to the rule. Cheater-detection does not work in the case of the abstract version of the Wason Selection Task as vowels and numbers do not behave or even cheat at all as opposed to human beings.

Inductive reasoning

In the previous sections deductive reasoning was discussed, reaching conclusions based on logical rules applied to a set of premises. However, many problems cannot be represented in a way that would make it possible to use these rules to get a conclusion. This subchapter is about a way to be able to decide in terms of these problems as well: inductive reasoning.

Inductive reasoning is the process of making simple observations of a certain kind and applying these observations via generalization to a different problem to make a decision. Hence one infers from a special case to the general principle which is just the opposite of the procedure of deductive reasoning (Figure 4). A good example for inductive reasoning is the following:

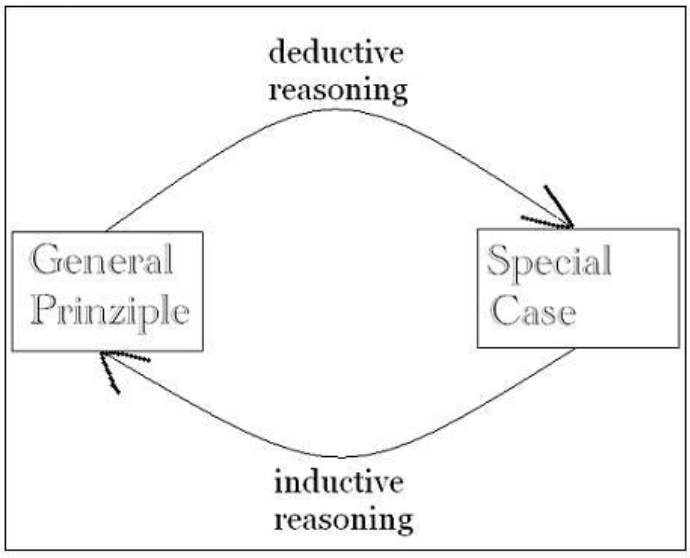

Figure 4, Deductive and inductive reasoning

```
Premise: All crows Knut and his wife have ever seen are black.
Conclusion: Therefore, they reason that all crows on earth are black.
```

In this example it is obvious that Knut and his wife infer from the simple observation about the crows they have seen to the general principle about all crows. Considering figure 5 this means that they infer from the subset (yellow circle) to the whole (blue circle). As in this example it is typical in a process of inductive reasoning that the premises are believed to support the conclusion, but do not ensure it.

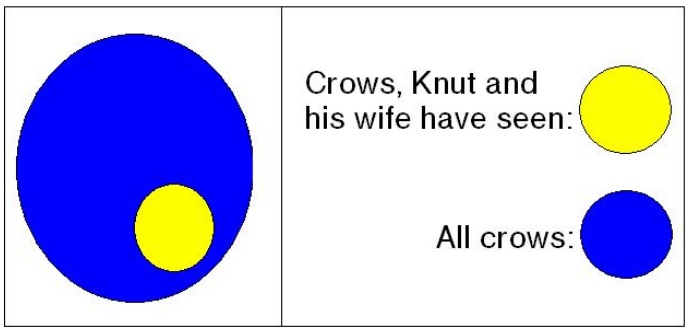

Figure 5

Forms of inductive reasoning

The two different forms of inductive reasoning are "**strong**" and "**weak**" induction. The former describes that the truth of the conclusion is very likely, if the assumed premises are true. An example for this form of reasoning is the one given in the previous section. In this case it is obvious that the premise ("All crows Knut and his wife have ever seen are black") gives good evidence for the conclusion ("All crows on earth are black") to be true. But nevertheless it is still possible, although very unlikely, that not all crows are black.

On the contrary, conclusions reached by "weak induction" are supported by the premises in a rather weak manner. In this approach the truth of the premises makes the truth of the conclusion possible, but not likely. An example for this kind of reasoning is the following:

```
Premise: Knut always hears music with his IPod.
Conclusion: Therefore, he reasons that all music is only heard with IPods.
```

In this instance the conclusion is obviously false. The information the premise contains is not very representative and although it is true, it does not give decisive evidence for the truth of the conclusion.

To sum it up, strong inductive reasoning gets to conclusions which are very probable whereas the conclusions reached through weak inductive reasoning on the base of the premises are unlikely to be true.

Reliability of conclusions

If the strength of the conclusion of an inductive argument has to be determined, three factors concerning the premises play a decisive role. The following example which refers to Knut and his wife and the observations they made about the crows (see previous sections) displays these factors:

When Knut and his wife observe in addition to the black crows in Germany also the crows in Spain, the **number of observations** they make concerning the crows obviously increases. Furthermore, the **representativeness of these observations** is supported, if Knut and his wife observe the crows at all different day- and nighttimes and see that they are black every time. Theoretically it may be that the crows change their colour at night what would make the conclusion that all crows are black wrong. The **quality of the evidence** for all crows to be black increases, if Knut and his wife add scientific measurements which support the conclusion. For example they could find out that the crows' genes determine that the only colour they can have is black.

Conclusions reached through a process of inductive reasoning are never definitely true as no one has seen all crows on earth and as it is possible, although very unlikely, that there is a green or brown exemplar. The three mentioned factors contribute decisively to the strength of an inductive argument. So, the stronger these factors are, the more reliable are the conclusions reached through induction.

Processes and constraints

In a process of inductive reasoning people often make use of certain heuristics which lead in many cases quickly to adequate conclusions but sometimes may cause errors. In the following, two of these heuristics (**availability heuristic** and **representativeness heuristic**) are explained. Subsequently, the **confirmation bias** is introduced which sometimes influences peoples' reasons according to their own opinion without them realising it.

The availability heuristic

Things that are more easily remembered are judged to be more prevalent. An example for this is an experiment done by Lichtenstein et al. (1978). The participants were asked to choose from two different lists the causes of death which occur more often. Because of the availability heuristic people judged more "spectacular" causes like homicide or tornado to cause more deaths than others, like asthma. The reason for the subjects answering in such a way is that for example films and news in television are very often about spectacular and interesting causes of death. This is why these information are much more available to the subjects in the experiment.

Another effect of the usage of the availability heuristic is called **illusory correlations**. People tend to judge according to stereotypes. It seems to them that there are correlations between certain events which in reality do not exist. This is what is known by the term "prejudice". It means that a much oversimplified generalization about a group of people is made. Usually a correlation seems to exist between negative features and a certain class of people (often fringe groups). If, for example, one's neighbour is jobless and very lazy one tends to correlate these two attributes and to create the prejudice that all jobless people are lazy. This illusory correlation occurs because one takes into account information which is available and judges this to be prevalent in many cases.

The representativeness heuristic

If people have to judge the probability of an event they try to find a comparable event and assume that the two events have a similar probability. Amos Tversky and Daniel Kahneman (1974) presented the following task to their participants in an experiment: "We randomly chose a man from the population of the U.S., Robert, who wears glasses, speaks quietly and reads a lot. Is it more likely that he is a librarian or a farmer?" More of the participants answered that Robert is a librarian which is an effect of the representativeness heuristic. The comparable event which the participants chose was the one of a typical librarian as Robert with his attributes of speaking quietly and wearing glasses resembles this event more than the event of a typical farmer. So, the event of a typical librarian is better comparable with Robert than the event of a typical farmer. Of course this effect may lead to errors as Robert is randomly chosen from the population and as it is perfectly possible that he is a farmer although he speaks quietly and wears glasses.

The representativeness heuristic also leads to errors in reasoning in cases where the **conjunction rule** is violated. This rule states that the conjunction of two events is never more likely to be the case than the single events alone. An example for this is the case of the feminist bank teller (Tversky & Kahneman, 1983). If we are introduced to a woman of whom we know that she is very interested in women's rights and has participated in many political activities in college and we are to decide whether it is more likely that she is a bank teller or a feminist bank teller, we are drawn to conclude the latter as the facts we have learnt about her resemble the event of a feminist bank teller more than the event of only being a bank teller.

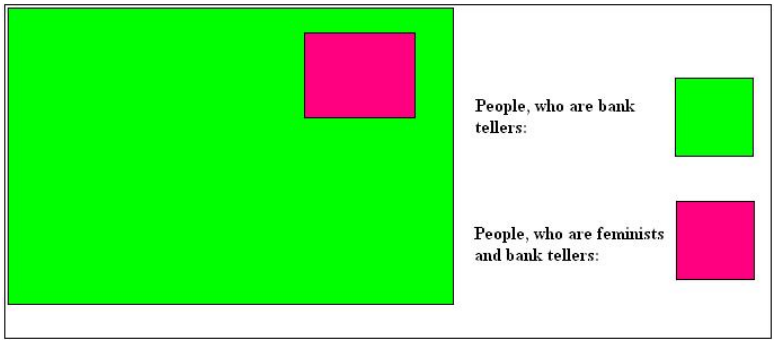

Figure 6, Feminist bank tellers

But it is in fact much more likely that somebody is just a bank teller than it is that someone is a feminist in addition to being a bank teller. This effect is illustrated in figure 6 where the green square, which stands for just being a bank teller, is much larger and thus more probable than the smaller violet square, which displays the conjunction of bank tellers and feminists, which is a subset of bank tellers.

The confirmation bias

This phenomenon describes the fact that people tend to decide in terms of what they themselves believe to be true or good. If, for example, someone believes that one has bad luck on Friday the thirteenth, he will especially look for every negative happening at this particular date but will be inattentive to negative happenings on other days. This behaviour strengthens the belief that there exists a relationship between Friday the thirteenth and having bad luck. This example shows that the actual information is not taken into account to come to a conclusion but only the information which supports one's own belief. This effect leads to errors as people tend to reason in a subjective manner, if personal interests and beliefs are involved.

All the mentioned factors influence the subjective probability of an event so that it differs from the actual probability (**probability heuristic**). Of course all of these factors do not always appear alone, but they influence one another and can occur in combination during the process of reasoning.

Why inductive reasoning at all?

All the described constraints show how prone to errors inductive reasoning is and so the question arises, why we use it at all?

But inductive reasons are important nevertheless because they act as shortcuts for our reasoning. It is much easier and faster to apply the availability heuristic or the representativeness heuristic to a problem than to take into account all information concerning the current topic and draw a conclusion by using logical rules.

In the following excerpt of very usual actions there is a lot of inductive reasoning involved although one does not realize it on the first view. It points out the importance of this cognitive ability:

The sunrise every morning and the sunset in the evening, the change of seasons, the TV program, the fact that a chair does not collapse when we sit on it or the light bulb that flashes after we have pushed a button.

All of these cases are conclusions derived from processes of inductive reasoning. Accordingly, one assumes that the chair one is sitting on does not collapse as the chairs on which one sat before did not collapse. This does not ensure that the chair does not break into pieces but nevertheless it is a rather helpful conclusion to assume that the chair remains stable as this is very probable. To sum it up, inductive reasoning is rather advantageous in situations where deductive reasoning is just not applicable because only evidence but no proved facts are available. As these situations occur rather often in everyday life, living without the use of inductive reasoning is inconceivable.

Induction vs. deduction

The table below (Figure 7) summarises the most prevalent properties and differences between deductive and inductive reasoning which are important to keep in mind.

	Deductive Reasoning	Inductive Reasoning
Premises	Stated as facts or general principles ("It is warm in the summer in Spain.").	Based on observations of specific cases ("All crows Knut and his wife have seen are black.").
Conclusion	Conclusion is more special than the information the premises provide. It is reached directly by applying logical rules to the premises.	Conclusion is more general than the information the premises provide. It is reached by generalizing the premises` information.
Validity	If the premises are true, the conclusion must be true.	If the premises are true, the conclusion is probably true.
Usage	More difficult to use (mainly in logical problems). One needs facts which are definitely true.	Used often in everyday life (fast and easy). Evidence is used instead of proved facts.

Figure 7, Induction vs. deduction

Decision making

According to the different levels of consequences, each process of making a decision requires appropriate effort and various aspects to be considered. The following excerpt from the story about Knut makes this obvious: “After considering facts like the warm weather in Spain and shirts and shorts being much more comfortable in this case (information gathering and likelihood estimation) Knut reasons that he needs them for his vacation. In consequence, he finally makes the decision to pack mainly shirts and shorts in his bag (final act of choosing).” Now it seems like there cannot be any decision making without previous reasoning, but that is not true. Of course there are situations in which someone decides to do something spontaneously, with no time to reason about it. We will not go into detail

here but you might think about questions like *"Why do we choose one or another option in that case?"*

Choosing among alternatives

The psychological process of decision making constantly goes along with situations in daily life. Thinking about Knut again we can imagine him to decide between packing more blue or more green shirts for his vacation (which would only have minor consequences) but also about applying a specific job or having children with his wife (which would have relevant influence on important circumstances of his future life). The mentioned examples are both characterized by personal decisions, whereas professional decisions, dealing for example with economic or political issues, are just as important.

The utility approach

There are three different ways to analyze decision making. The normative approach assumes a rational decision-maker with well-defined preferences. While the rational choice theory is based on a priori considerations, the descriptive approach is based on empirical observations and on experimental studies of choice behavior. The prescriptive enterprise develops methods in order to improve decision making. According to Manktelow and Reber´s definition, "utility refers to outcomes that are desirable because they are in the person's best interest" (Reber, A. S., 1995; Manktelow, K., 1999). This normative/descriptive approach characterizes optimal decision making by the maximum expected utility in terms of monetary value. This approach can be helpful in gambling theories, but simultaneously includes several disadvantages. People do not necessarily focus on the monetary payoff, since they find value in things other than money, such as fun, free time, family, health and others. But that is not a big problem, because it is possible to apply the graph (Figure 8), which shows the relation between (monetary) gains/losses and their subjective value / utility, which is equal to all the valuable things mentioned above. Therefore, not choosing the maximal monetary value does not automatically describe an irrational decision process.

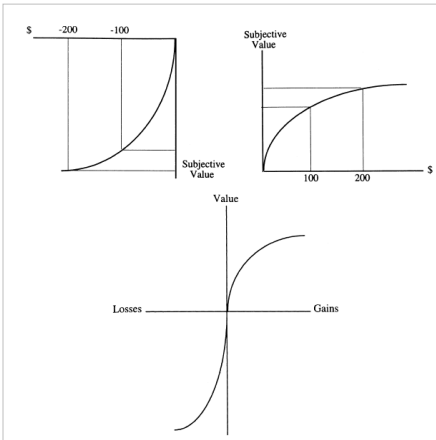

Figure 8, Relation between (monetary) gains/losses and their subjective value

Misleading effects

But even respecting the considerations above there might still be problems to make the "right" decision because of different misleading effects, which mainly arise because of the constraints of inductive reasoning. In general this means that our model of a situation/problem might not be ideal to solve it in an optimal way. The following three points are typical examples for such effects.

Subjective models

This effect is rather equal to the illusory correlations mentioned before in the part about the constraints of inductive reasoning. It is about the problem that models which people create might be misleading, since they rely on subjective speculations. An example could be deciding where to move by considering typical prejudices of the countries (e.g. always good pizza, nice weather and a relaxed life-style in Italy in contrast to some kind of boring food and steady rain in Great Britain). The predicted events are not equal to the events occurring indeed. (Kahneman & Tversky, 1982; Dunning & Parpal, 1989)

Focusing illusion

Another misleading effect is the so-called **focusing illusion**. By considering only the most obvious aspects in order to make a certain decision (e.g. the weather) people often neglect various really important outcomes (e.g. circumstances at work). This effect occurs more often, if people judge about others compared with judgments about

their own living.

Framing effect

A problem can be described in different ways and therefore evoke different decision strategies. If a problem is specified in terms of gains, people tend to use a risk-aversion strategy, while a problem description in terms of losses leads to apply a risk-taking strategy. An example of the same problem and predictably different choices is the following experiment: A group of people is asked to imagine themselves $300 richer than they are, is confronted with the choice of a sure gain of $100 or an equal chance to gain $200 or nothing. Most people avoid the risk and take the sure gain, which means they take the risk-aversion strategy. Alternatively if people are asked to assume themselves to be $500 richer than in reality, given the options of a sure loss of $100 or an equal chance to lose $200 or nothing, the majority opts for the risk of losing $200 by taking the risk seeking or risk-taking strategy. This phenomenon is known as **framing effect** and can also be illustrated by figure 8 above, which is a concave function for gains and a convex one for losses. (*Foundations of Cognitive Psychology*, Levitin, D. J., 2002)

Justification in decision making

Decision making often includes the need to assign a reason for the decision and therefore justify it. This factor is illustrated by an experiment by A. Tversky and E. Shafir (1992): A very attractive vacation package has been offered to a group of students who have just passed an exam and to another group of students who have just failed the exam and have the chance to rewrite it after the holidays coming up. All students have the options to buy the ticket straight away, to stay at home, or to pay $5 for keeping the option open to buy it later. At this point, there is no difference between the two groups, since the number of students who passed the exam and decided to book the flight (with the justification of a deserving a reward), is the same as the number of students who failed and booked the flight (justified as consolation and having time for reoccupation). A third group of students who were informed to receive their results in two more days was confronted with the same problem. The majority decided to pay $5 and keep the option open until they would get their results. The conclusion now is that even though the actual exam result does not influence the decision, it is required in order to provide a rationale.

Executive functions

Subsequently, the question arises how this cognitive ability of making decisions is realized in the human brain. As we already know that there are a couple of different tasks involved in the whole process, there has to be something that coordinates and controls those brain activities – namely the **executive functions**. They are the brain's conductor, instructing other brain regions to perform, or be silenced, and generally coordinating their synchronized activity (Goldberg, 2001). Thus, they are responsible for optimizing the performance of all "multi-threaded" cognitive tasks.

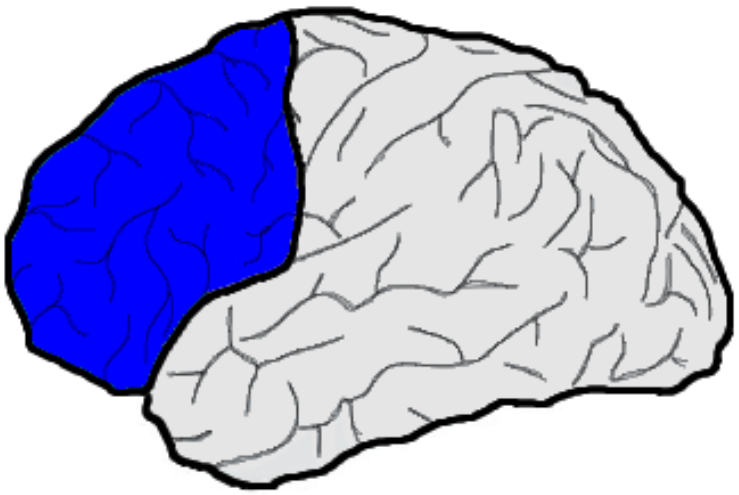

Figure 9, Left frontal lobe

Locating those executive functions is rather difficult, as they cannot be appointed to a single brain region. Traditionally, they have been equated with the frontal lobes, or rather the prefrontal regions of the frontal lobes; but it is still an open question whether all of their aspects can be associated with these regions.

Nevertheless, we will concentrate on the prefrontal regions of the frontal lobes, to get an impression of the important role of the executive functions within cognition. Moreover, it is possible to subdivide these regions into functional parts. But it is to be noted that not all researchers regard the prefrontal cortex as containing functionally different regions.

Executive functions in practise

According to Norman and Shallice, there are five types of situations in which executive functions may be needed in order to optimize performance, as the automatic activation of behaviour would be insufficient. These are situations involving...

1. ...planning or decision making.

2. ...error correction or trouble shooting.

3. ...responses containing novel sequences of actions.

4. ...technical difficulties or dangerous circumstances.

5. ...the control of action or the overcoming of strong habitual responses.

The following parts will have a closer look to each of these points, mainly referring to brain-damaged individuals.

Surprisingly, intelligence in general is not affected in cases of frontal lobe injuries (Warrington, James & Maciejewski, 1986). However, dividing intelligence into **crystallised intelligence** (based on previously acquired knowledge) and **fluid intelligence** (meant to rely on the current ability of solving problems), emphasizes the executive power of the frontal lobes, as patients with lesions in these regions performed significantly worse in tests of fluid intelligence (Duncan, Burgess & Emslie, 1995).

1. Planning or decision making

Impairments in abstract and conceptual thinking

To solve many tasks it is important that one is able to use given information. In many cases, this means that material has to be processed in an abstract rather than in a concrete manner. Patients with executive dysfunction have abstraction difficulties. This is proven by a card sorting experiment (Delis et al., 1992):

The cards show names of animals and black or white triangles placed above or below the word. Again, the cards can be sorted with attention to different attributes of the animals (living on land or in water, domestic or dangerous, large or small) or the triangles (black or white, above or below word). People with frontal lobe damage fail to solve the task because they cannot even conceptualize the properties of the animals or the triangles, thus are not able to deduce a sorting-rule for the cards (in contrast, there are some individuals only perseverating; they find a sorting-criterion, but are unable to switch to a new one).

These problems might be due to a general difficulty in strategy formation.

Goal directed behavior

Let us again take Knut into account to get an insight into the field of goal directed behaviour – in principle, this is nothing but problem solving since it is about organizing behavior towards a goal. Thus, when Knut is packing his bag for his holiday, he obviously has a goal in mind (in other words: He wants to solve a problem) – namely get ready before the plane starts. There are several steps necessary during the process of reaching a certain goal:

Goal must be kept in mind

Knut should never forget that he has to pack his bag in time.

Dividing into subtasks and sequencing

Knut packs his bag in a structured way. He starts packing the crucial things and then goes on with rest.

Completed portions must be kept in mind

If Knut already packed enough underwear into his bag, he would not need to search for more.

Flexibility and adaptability

Imagine that Knut wants to pack his favourite T-Shirt, but he realizes that it is dirty. In this case, Knut has to adapt to this situation and has to pick another T-Shirt that was not in his plan originally.

Evaluation of actions

Along the way of reaching his ultimate goal Knut constantly has to evaluate his performance in terms of 'How am I doing considering that I have the goal of packing my bag?'.

Executive dysfunction and goal directed behavior

The breakdown of executive functions impairs goal directed behavior to a large extend. In which way cannot be stated in general, it depends on the specific brain regions that are damaged. So it is quite possible that an individual with a particular lesion has problems with two or three of the five points described above and performs within average regions when the other abilities are tested. However, if only one link is missing from the chain, the whole plan might get very hard or even impossible to master. Furthermore, the particular hemisphere affected plays a role as well.

Another interesting result was the fact that lesions in the frontal lobes of left and right hemisphere impaired different abilities. While a lesion in the right hemisphere caused trouble in making recency judgements, a lesion in the left hemisphere impaired the patient's performance only when the presented material was verbal or in a variation of the experiment that required self-ordered sequencing. Because of that we know that the ability to sequence behaviour is not only located in the frontal lobe but in the left hemisphere particularly when it comes to motor action.

Problems in sequencing

In an experiment by Milner (1982), people were shown a sequence of cards with pictures. The experiment included two different tasks: recognition trials and recency trials. In the former the patients were shown two different pictures, one of them has appeared in the sequence before, and the participants had to decide which one it was. In the latter they were shown two different pictures, both of them have appeared before, they had to name the picture that was shown more recently than the other one. The results of this experiment showed that people with lesions in temporal regions have more trouble with the recognition trial and patients with frontal lesions have difficulties with the recency trial since anterior regions are important for sequencing. This is due to the fact that the recognition trial demanded a properly functioning recognition memory [3], the recency trial a properly functioning memory for item order [3]. These two are dissociable and seem to be processed in different areas of the brain.

The frontal lobe is not only important for sequencing but also thought to play a major role for working memory [3]. This idea is supported by the fact that lesions in the lateral regions of the frontal lobe are much more likely to impair the ability of 'keeping things in mind' than damage to other areas of the frontal cortex do.

But this is not the only thing there is to sequencing. For reaching a goal in the best possible way it is important that a person is able to figure out which sequence of actions, which strategy, best suits the purpose, in addition to just being able to develop a correct sequence. This is proven by an experiment called 'Tower of London' (Shallice, 1982) which is similar to the famous 'Tower of Hanoi' [4] task with the difference that this task required three balls to be put onto three poles of different length so that one pole could hold three balls, the second one two and the third one only one ball, in a way that a changeable goal position is attained out of a fixed initial position in as few moves as possible. Especially patients with damage to the left frontal lobe proved to work inefficiently and ineffectively on this task. They needed many moves and engaged in actions that did not lead toward the goal.

Problems with the interpretation of available information

Quite often, if we want to reach a goal, we get hints on how to do it best. This means we have to be able to interpret the available information in terms of what the appropriate strategy would be. For many patients of executive dysfunction this is not an easy thing to do either. They have trouble to use this information and engage in inefficient actions. Thus, it will take them much longer to solve a task than healthy people who use the extra information and develop an effective strategy.

Problems with self-criticism and -monitoring

The last problem for people with frontal lobe damage we want to present here is the last point in the above list of properties important for proper goal directed behavior. It is the ability to evaluate one's actions, an ability that is missing in most patients. These people are therefore very likely to 'wander off task' and engage in behavior that does not help them to attain their goal. In addition to that, they are also not able to determine whether their task is already completed at all. Reasons for this are thought to be a lack of motivation or lack of concern about one's performance (frontal lobe damage is usually accompanied by changes in emotional processing) but these are probably not the only explanations for these problems.

Another important brain region in this context – the medial portion of the frontal lobe – is responsible for detecting behavioral errors made while working towards a goal. This has been shown by ERP experiments [5] where there was an error-related negativity 100ms after an error has been made. If this area is damaged, this mechanism cannot work properly anymore and the patient loses the ability to detect errors and thus monitor his own behavior.

However, in the end we must add that although executive dysfunction causes an enormous number of problems in behaving correctly towards a goal, most patients when assigned with a task are indeed anxious to solve it but are just unable to do so.

2. Error correction and trouble shooting

The most famous experiment to investigate error correction and trouble shooting is the Wisconsin Card Sorting Test (WCST). A participant is presented with cards that show certain objects. These cards are defined by shape, color and number of the objects on the cards. These cards now have to be sorted according to a rule based on one of these three criteria. The participant does not know which rule is the right one but has to reach the conclusion after positive or negative feedback of the experimenter. Then at some point, after the participant has found the correct rule to sort the cards, the experimenter changes the rule and the previous correct sorting will lead to negative feedback. The participant has to realize the change and adapt to it by sorting the cards according to the new rule.

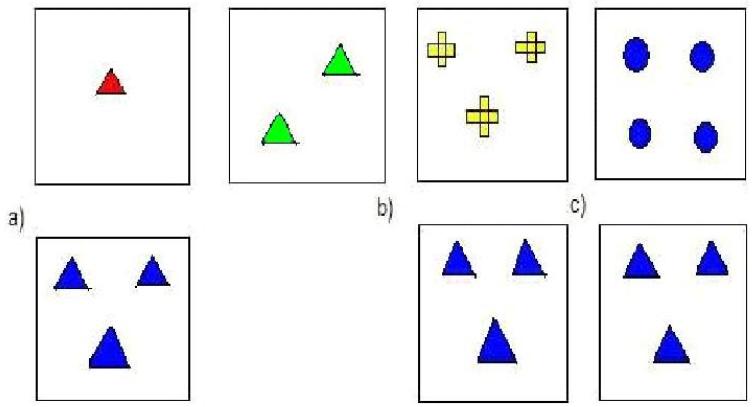

Figure 10, Example for the WCST: Cards sorted according to shape (a), number (b) or color (c) of the objects

Patients with executive dysfunction have problems identifying the rule in the first place. It takes them noticeably longer because they have trouble using already given information to make a conclusion. But once they got to sorting correctly and the rule changes, they keep sorting the cards according to the old rule although many of them notice the negative feedback. They are just not able to switch to another sorting-principle, or at least they need many tries to learn the new one. They **perseverate**.

Problems in shifting and modifying strategies

Intact neuronal tissue in the frontal lobe is also crucial for another executive function connected with goal directed behavior that we described above: Flexibility and adaptability. This means that persons with frontal lobe damage will have difficulties in shifting their way of thinking – meaning creating a new plan after recognizing that the original one cannot be carried out for some reason. Thus, they are not able to modify their strategy according to this new problem. Even when it is clear that one hypothesis cannot be the right one to solve a task, patients will stick to it nevertheless and are unable to abandon it (called 'tunnel vision').

Moreover, such persons do not use as many appropriate hypotheses for creating a strategy as people with damage to other brain regions do. In what particular way this can be observed in patients can again not be stated in general but depends on the nature of the shift that has to be made.

These earlier described problems of 'redirecting' of one's strategies stand in contrast to the atcual 'act of switching' between tasks. This is yet another problem for patients with frontal lobe damage. Since the control system that leads task switching as such is independent from the parts that actually perform these tasks, the task switching is particularly impaired in patients with lesions to the dorsolateral prefrontal cortex while at the same time they have no trouble with performing the single tasks alone. This of course, causes a lot of problems in goal directed behavior because as it was said before: Most tasks consist of smaller subtasks that have to be completed.

3. Responses containing novel sequences of actions

Many clinical tests have been done, requiring patients to develop strategies for dealing with novel situations. In the Cognitive Estimation Task (Shallice & Evans, 1978) patients are presented with questions whose answers are unlikely to be known. People with damage to the prefrontal cortex have major difficulties to produce estimates for questions like: “How many camels are in Holland?”.

In the FAS Test (Miller, 1984) subjects have to generate sequences of words (not proper names) beginning with a certain letter (“F” , “A” or “S”) in a one-minute period. This test involves developing new strategies, selecting between alternatives and avoiding repeating previous given answers. Patients with left lateral prefrontal lesions are often impaired (Stuss et al., 1998).

4. Technical difficulties or dangerous circumstances

One single mistake in a dangerous situation may easily lead to serious injuries while a mistake in a technical difficult situation (e.g. building a house of cards) would obviously lead to failure. Thus, in such situations, automatic activation of responses clearly would be insufficient and executive functions seem to be the only solution for such problems.

Wilkins, Shallice and McCarthy (1987) were able to prove a connection between dangerous or difficult situations and the prefrontal cortex, as patients with lesions to this area were impaired during experiments concerning dangerous or difficult situations. The ventromedial and orbitofrontal cortex may be particularly important for these aspects of executive functions.

5. Control of action or the overcoming of strong habitual responses

Deficits in initiation, cessation and control of action

We start by describing the effects of the loss of the ability to start something, to initiate an action. A person with executive dysfunction is likely to have trouble beginning to work on a task without strong help from the outside, while people with left frontal lobe damage often show impaired spontaneous speech and people with right frontal lobe damage rather show poor nonverbal fluency. Of course, one reason is the fact that this person will not have any intention, desire or concern on his or her own of solving the task since this is yet another characteristic of executive dysfunction. But it is also due to a psychological effect often connected with the loss of properly executive functioning: Psychological inertia. Like in physics, inertia in this case means that an action is very hard to initiate, but once started, it is again very hard to shift or stop. This phenomenon is characterized by engagement in repetitive behavior, is called perseveration (cp. WCST [6]).

Another problem caused by executive dysfunction can be observed in patients suffering from the so called **environmental dependency syndrome**. Their actions are impelled or obligated by their physical or social environment. This manifests itself in many different ways and depends to a large extent on the individual’s personal history. Examples are patients who begin to type when they see a computer key board, who start washing the dishes upon seeing a dirty kitchen or who hang up pictures on the walls when finding hammer, nails and pictures on the floor. This makes these people appear as if they were acting impulsively or as if they have lost their ‘free will’. It shows a lack of control for their actions. This is due to the fact that an impairment in their executive functions causes

a disconnection between thought and action. These patients know that their actions are inappropriate but like in the WCST, they cannot control what they are doing. Even if they are told by which attribute to sort the cards, they will still keep sorting them sticking to the old rule due to major difficulties in the translation of these directions into action.

What is needed to avoid problems like these are the abilities to start, stop or change an action but very likely also the ability to use information to direct behavior.

Deficits in cognitive estimation

Next to the difficulties to produce estimates to questions whose answers are unlikely known, patients with lesions to the frontal lobes have problems with cognitive estimation in general.

Cognitive estimation is the ability to use known information to make reasonable judgments or deductions about the world. Now the inability for cognitive estimation is the third type of deficits often observed in individuals with executive dysfunction. It is already known that people with executive dysfunction have a relatively unaffected knowledge base. This means they cannot retain knowledge about information or at least they are unable to make inferences based on it. There are various effects which are shown on such individuals. Now for example patients with frontal lobe damage have difficulty estimating the length of the spine of an average woman. Making such realistic estimations requires inferencing based on other knowledge which is in this case, knowing that the height of the average woman is about 5ft 6 in (168cm) and considering that the spine runs about one third to one half the length of the body and so on. Patients with such a dysfunction do not only have difficulties in their estimates of cognitive information but also in their estimates of their own capacities (such as their ability to direct activity in goal – oriented manner or in controlling their emotions). Prigatuno, Altman and O'Brien (1990) reported that when patients with anterior lesions associated with diffuse axonal injury to other brain areas are asked how capable they are of performing tasks such as scheduling their daily activities or preventing their emotions from affecting daily activities, they grossly overestimate their abilities. From several experiments Smith and Miler (1988) found out that individuals with frontal lobe damages have no difficulties in determining whether an item was in a specific inspection series they find it difficult to estimate how frequently an item did occur. This may not only reflect difficulties in cognitive estimation but also in memory task that place a premium on remembering temporal information. Thus both difficulties (in cognitive estimation and in temporal sequencing) may contribute to a reduced ability to estimate frequency of occurrence.

Despite these impairments in some domains the abilities of estimation are preserved in patients with frontal lobe damage. Such patients also do have problems in estimating how well they can prevent their emotions for affecting their daily activities. They are also as good at judging how many dues they will need to solve a puzzle as patients with temporal lobe damage or neurologically intact people.

Theories of frontal lobe function in executive control

In order to explain that patients with frontal lobe damage have difficulties in performing executive functions, four major approaches have developed. Each of them leads to an improved understanding of the role of frontal regions in executive functions, but none of these theories covers all the deficits occurred.

Role of working memory

The most anatomically specific approach assumes the dorsolateral prefrontal area of the frontal lobe to be critical for working memory. The working memory which has to be clearly distinguished from the long term memory keeps information on-line for use in performing a task. Not being generated for accounting for the broad array of dysfunctions it focuses on the three following deficits:

```
1.)Sequencing information and directing behavior toward a goal
2.)Understanding of temporal relations between items and events
3.)Some aspects of environmental dependency and perseveration
```

Research on monkeys has been helpful to develop this approach (the delayed-response paradigm, Goldman-Rakic, 1987, serves as a classical example).

Role of Controlled Versus Automatic Processes

There are two theories based on the underlying assumption that the frontal lobes are especially important for controlling behavior in non-experienced situations and for overriding stimulus-response associations, but contribute little to automatic and effortless behavior (Banich, 1997).

Stuss and Benson (1986) consider control over behavior to occur in a hierarchical manner. They distinguish between three different levels, of which each is associated with a particular brain region. In the first level sensory information is processed automatically by posterior regions, in the next level (associated with the executive functions of the frontal lobe) conscious control is needed to direct behavior toward a goal and at the highest level controlled self-reflection takes place in the prefrontal cortex.

This model is appropriate for explaining deficits in goal-oriented behavior, in dealing with novelty, the lack of cognitive flexibility and the environmental dependency syndrome. Furthermore it can explain the inability to control action consciously and to criticise oneself. The second model developed by Shalice (1982) proposes a system consisting of two parts that influence the choice of behavior. The first part, a cognitive system called contention scheduling, is in charge of more automatic processing. Various links and processing schemes cause a single stimulus to result in an automatic string of actions. Once an action is initiated, it remains active until inhibited. The second cognitive system is the supervisory attentional system which directs attention and guides action through decision processes and is only active "when no processing schemes are available, when the task is technically difficult, when problem solving is required and when certain response tendencies must be overcome" (Banich , 1997).

This theory supports the observations of few deficits in routine situations, but relevant problems in dealing with novel tasks (e.g. the Tower of London task, Shallice, 1982), since no schemes in contention scheduling exist for dealing with it. Impulsive action is another characteristic of patients with frontal lobe damages which can be explained by this theory. Even if asked not to do certain things, such patients stick to their routines and cannot control their automatic behavior.

Use of Scripts

The approach based on scripts, which are sets of events, actions and ideas that are linked to form a unit of knowledge was developed by Schank (1982) amongst others.

Containing information about the setting in which an event occurs, the set of events needed to achieve the goal and the end event terminating the action. Such managerial knowledge units (MKUs) are supposed to be stored in the prefrontal cortex. They are organized in a hierarchical manner being abstract at the top and getting more specific at the bottom.

Damage of the scripts leads to the inability to behave goal-directed, finding it easier to cope with usual situations (due to the difficulty of retrieving a MKU of a novel event) and deficits in the initiation and cessation of action (because of MKUs specifying the beginning and ending of an action.)

Role of a goal list

The perspective of artificial intelligence and machine learning introduced an approach which assumes that each person has a goal list, which contains the tasks requirements or goals. This list is fundamental to guiding behavior and since frontal lobe damages disrupt the ability to form a goal list, the theory helps to explain difficulties in abstract thinking, perceptual analysis, verbal output and staying on task. It can also account for the strong environmental influence on patients with frontal lobe damages, due to the lack of internal goals and the difficulty of organizing actions toward a goal.

Brain Region	Possible Function (left hemisphere)	Possible Function (right hemisphere)	Brodman's Areas which are involved
ventrolateral prefrontal cortex (VLPFC)	Retrieval and maintenance of semantic and/or linguistic information	Retrieval and maintenance of visuospatial information	44, 45, 47 (44 & 45 = Broca's Area)
dorsolateral prefrontal cortex)DLPRF)	Selecting a range of responses and suppressing inappropriate ones; manipulating the contents of working memory	Monitoring and checking of information held in mind, particularly in conditions of uncertainty; vigilance and sustained attention	9, 46
anterior prefrontal cortex; frontal pole; rostral prefrontal cortex	Multitasking; maintaining future intentions & goals while currently performing other tasks or subgoals	same	10
anterior cingulate cortex (dorsal)	Monitoring in situations of response conflict and error detection	same	24 (dorsal) & 32 (dorsal)

Summary

It is important to keep in mind that reasoning and decision making are closely connected to each other: Decision making in many cases happens with a previous process of reasoning. People's everyday life is decisively coined by the synchronized appearance of these two human cognitive features. This synchronization, in turn, is realized by the executive functions which seem to be mainly located in the frontal lobes of the brain.

References

• Goldstein, E. Bruce (2005). Cognitive Psychology - Connecting, Mind Research, and Everyday Experience. Thomson Wadsworth.

• Marie T. Banich (1997). Neuropsychology. The neural bases of Mental Function. Houghton Mifflin.

• Wilson, Robert A.& Keil, Frank C. (1999). The MIT Encyclopedia of the Cognitive Sciences. Massachusetts: Bradford Book.

• Ward, Jamie (2006). The Student's Guide To Cognitive Science. Psychology Press.

• Levitin, D. J.(2002). Foundations of Cognitve Psychology.

• Schmalhofer, Franz. Slides from the course: Cognitive Psychology and Neuropsychology, Summer Term 2006/2007, University of Osnabrueck

Links

Reasoning

Quizz to check whether you understood the difference of deduction and induction [7]

Short text with graphics [8]

Reasoning in geometry [9]

Euler circles [10]

Wason Selection Task [11]

Difference: Induction, Deduction [12]

Decision making

How to make good decisions [13]

Making ethical decisions [14]

Web-published journal by the Society for Judgement and Decision Making [15]

Executive functions

Elaborate document (pdf) from the Technical University of Dresden (in German) [16]

Text from the Max Planck Society, Munich (in English) [17]

Short description and an extensive link list [18]

Executive functions & ADHD [19]

References

[1] http://en.wikipedia.org/wiki/Wason_selection_task
[2] http://en.wikibooks.org/wiki/Cognitive_Psychology_and_Cognitive_Neuroscience/Evolutionary_Perspective_on_Social_Cognitions
[3] http://en.wikibooks.org/wiki/Cognitive_Psychology_and_Cognitive_Neuroscience/Memory
[4] http://en.wikibooks.org/wiki/Cognitive_Psychology_and_Cognitive_Neuroscience/Problem_Solving_from_an_Evolutionary_Perspective#Means-End_Analysis
[5] http://en.wikibooks.org/wiki/Cognitive_Psychology_and_Cognitive_Neuroscience/Behavioural_and_Neuroscience_Methods#ERP
[6] http://en.wikibooks.org/wiki/Cognitive_Psychology_and_Cognitive_Neuroscience/Reasoning_and_Decision_Making#2.__Error_correction_and_trouble_shooting
[7] http://www.sjsu.edu/depts/itl/graphics/induc/ind-ded.html
[8] http://www.socialresearchmethods.net/kb/dedind.htm
[9] http://www.sparknotes.com/math/geometry3/inductiveanddeductivereasoning/summary.html
[10] http://www.ltg.ed.ac.uk/~richard/Java/Euler/
[11] http://coglab.wadsworth.com/experiments/WasonSelection.shtml
[12] http://www.personal.kent.edu/~rmuhamma/Algorithms/MyAlgorithms/DeductInduct.htm
[13] http://www.mindtools.com/pages/main/newMN_TED.htm
[14] http://www.josephsoninstitute.org/MED/MED-intro+toc.htm
[15] http://journal.sjdm.org/
[16] http://www.psychologie.tu-dresden.de/allgpsy/Mayer/ek.pdf
[17] http://www.mpipf-muenchen.mpg.de/CA/RESEARCH/executive_e.html
[18] http://pnpic.org/exec_fun.htm
[19] http://www.lehighpsych.com/art_adhd.htm

Article Sources and Contributors

Cognitive Psychology and Cognitive Neuroscience/Reasoning and Decision Making *Source*: http://en.wikibooks.org/w/index.php?oldid=2064116 *Contributors*: Adrignola, Avicennasis, Jherding, Maltewoest, Mbrauner, Mike.lifeguard, 9 anonymous edits

Image Sources, Licenses and Contributors

Image:eulercircles.jpg *Source*: http://en.wikibooks.org/w/index.php?title=File:Eulercircles.jpg *License*: Public Domain *Contributors*: User:Maltewoest at Wikibooks

Image:syllo.jpg *Source*: http://en.wikibooks.org/w/index.php?title=File:Syllo.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: Original uploader was Maltewoest at en.wikibooks

Image:wason1.jpg *Source*: http://en.wikibooks.org/w/index.php?title=File:Wason1.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: Franz Josef Schmalhofer Original uploader was Maltewoest at en.wikibooks

Image:reasoning.jpg *Source*: http://en.wikibooks.org/w/index.php?title=File:Reasoning.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: Original uploader was Maltewoest at en.wikibooks

Image:crows.jpg *Source*: http://en.wikibooks.org/w/index.php?title=File:Crows.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: Original uploader was Maltewoest at en.wikibooks

Image:feminist bank teller.jpg *Source*: http://en.wikibooks.org/w/index.php?title=File:Feminist_bank_teller.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: Original uploader was Maltewoest at en.wikibooks

Image:invsde.jpg *Source*: http://en.wikibooks.org/w/index.php?title=File:Invsde.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: Original uploader was Maltewoest at en.wikibooks

Image:value.png *Source*: http://en.wikibooks.org/w/index.php?title=File:Value.png *License*: Public Domain *Contributors*: Original uploader was Mbrauner at en.wikibooks

Image:frontallobes.png *Source*: http://en.wikibooks.org/w/index.php?title=File:Frontallobes.png *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: Jan Herding Jherding

Image:wcst.jpg *Source*: http://en.wikibooks.org/w/index.php?title=File:Wcst.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: Original uploader was Maltewoest at en.wikibooks

License