COGNITIVE PSYCHOLOGY AND COGNITIVE NEUROSCIENCE

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1 Cognitive Psychology and the Brain

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Introduction

Imagine a young man, Knut, sitting at his desk, with his tired eyes staring at a monitor, surfing around, trying to find some worthy articles for his psychology homework. A cigarette rests between the middle and index fingers of his left hand. Without looking, he stretches out his free hand and grabs a cup of coffee located on the right of his keyboard. While sipping some of the cheap discounter blend, he suddenly asks himself: "What is happening here?"

Around the beginning of the 20th century, psychologists would have said, "Take a look into yourself, Knut, analyse what you're thinking and doing," as analytical introspection was the method of that time.

A few years later, J.B. Watson published his book *Psychology from the Standpoint of a Behaviorist*, from which began the era of behaviourism. Behaviourists claimed that it was impossible to study the inner life of people scientifically. Their approach to psychology, which they assumed to be more scientific, focussed only on the study and experimental analysis of behaviour. The right answer to Knut's question would have been: "You are sitting in front of your computer, reading and drinking coffee, because of your environment and how it influences you." Behaviorism was the primary means for American psychology for about the next 50 years. One of the primary critiques and downfalls of behaviorism was Noam Chomsky's 1959 critique of B.F. Skinner's "Verbal behaviour". Skinner, an influential behaviourist, attempted to explain language on the basis of behaviour alone. Chomsky showed that this was impossible, and by doing so, influenced enough psychologists to end the dominance of behaviorism in American psychology.

As more researchers were once again concerned with processes inside the head, cognitive psychology arose on the landscape of science. Their central claim was that cognition was information processing of the brain. Cognitive psychology did not dispose the methods of behaviourism, but rather widened their horizon by adding levels between input and output.

Modern technology and new methods enabled researchers to combine examinations of public actions (latencies in reaction time, number of recalls) with physiological measurements (EEG and event-related potentials, fMRI). Such methods, in addition to others, are used by cognitive science to collect evidence for certain features of mental activity. From this, references and correlations between action and cognition could be made.

These correlations were inspiration and thenceforwards the main challenge for cognitive psychologists. To answer Knut's question the cognitive psychologist would probably first examining Knut’s brain in that specific situation. So let's try this!

Knut has a problem, he really needs to do his homework. To solve this problem, he has to perform loads of cognition. The light is gleaming into his eyes, transducing it from his retina into nerve signals by sensory cells. The information is passed on through the optic nerve, crosses the brain at the lateral geniculate nucleus to arrive at the central visual cortex. On its journey, the signals get computed over complex nets of neurons; the contrast of the picture gets enhanced; irrelevant information gets filtered out; patterns are recognized; stains and lines on the screen become words; words get meaning, the meaning is put into context, analyzed on its relevance for Knut's problem, maybe stored in some part of memory. At the same time an appetite for coffee is creeping from Knut's hypothalamus, a region in the brain responsible for controlling the needs of an organism. The appetite, encoded in patterns of neural information, makes its way to the motor cortex where it is passed on to the muscles into Knut's arm.

A lot more could be said about this, and Knut's question remains unanswered, but this should be enough to point out the complexity of cognition and the brain's importance. In this chapter, we are going to dig deeper into the question of what cognitive psychology is and how it became this way, and then draw connections to the brain and explain some of its most important parts.

Defining Cognitive Psychology

Cognitive Psychology is a psychological science which is interested in various mind and brain related subfields such as cognition, the mental processes that underlie behavior, reasoning and decision making.

In the early stages of Cognitive Psychology, the high-tech measuring instruments used today were unavailable. The idea of scientifically scrutinizing what was going on in a human mind was first established during the late 19th century.

Psychology Laboratories were based on measuring observable features such as *reaction time*. Nonetheless, there was a technique developed called *analytic* introspection. The latter is a method that focusses on the subject's inner processes. Here, the subject has to give precise reports about his or her mental activity.

During the first half of the 20th century and naturally parallel to behaviorism, the behavioristic approach became the main issue in psychology. The main emphasis was the examination of outer expression of inner processes, rather than the mind itself.

Even though behaviorism had established itself as the mainstream, curiosity about the mind was not diminished. In the 1950s, this inquisitiveness was released in a new science named Cognitive Science. Cognitive Psychology became one of its subfields. The interdisciplinary approach of Cognitive Science enabled the use of modern technology and new methods to combine examinations of *public actions* (latencies in reaction time, number of recalls) with physiological measurements (EEG and event-related potentials, fMRI).

Hereby, references and correlations between action and cognition could be made. Cognitive Psychology is using these methods and additional ones such as *Single and Double* Dissociation and *brain lesioning* to collect evidence for certain features of mental activity. Because of those correlations that were found, the examination of the human brain and its functions has become one of the main challenges to Cognitive Psychology.

The role of the brain

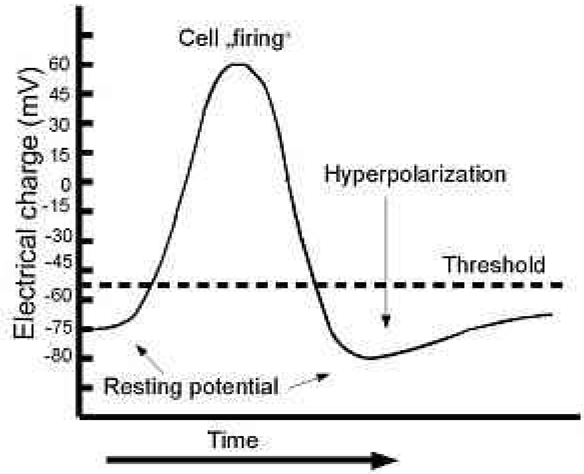

Figure 1.1 - The resting potential is initially around -70 mV relative to the outside of the cell. Once the threshold (-55 mV) is passed, the cell depolarizes and the polarity reverses up to +40 mV. Subsequently the cell hyperpolarizes and the voltage becomes more negative than the resting potential for a short period.

Examination of brain damage has a long tradition. The Ancient Romans observed that gladiators with head injuries often lost their mental skills, whereas injuries to other parts of the body did not have such an effect. It was inferred that there was a possible link between the mind and brain. Today, the assumption that the mind is somehow implemented in the brain is taken for granted, and even the common-sense understanding presupposes a relation between mental and neuronal processes. Subsequently, research on the brain became more and more important, and the psychological methods being used shifted to systematic scientific examination of the brain. The crucial question then became: How is this relation realized, and what properties of the brain are capable of causing mental and cognitive events?

As it is not possible, in this introductory passage, to cover the entire configuration of the brain in an appropriate manner, we will just give a brief summary of the concepts behind neural signal transduction, and smoothly switch over to the anatomy of the brain. This in turn will then serve as background information in the attempt to link cognitive functions to brain structure.

In principle, there are two classes of cells in the human brain: **neurons** and glia. Both are approximately equal in distribution, though neurons seem to play the main role in information processing. The actual signal transduction takes place in different ways. On the one hand, there is mean electrical conduction, and on the other hand, there are complicated biochemical cascades which transmit the data. Both variants can be subsumed to the concept of action potentials (Figure 1.1), which generally carry out the signal transduction from one nerve cell to another.

For better conduction, the axons of the neurons are insulated by a so-called myelin sheath. The myelin in the human brain is produced by a certain class of glial cell, the oligodendrocytes. This is important because the decomposition of the myelin sheath is involved in diseases, such as as multiple sklerosis.

Once the information perceived by the sensory organs is transformed into a sequence of **action potentials** the data is, in a way, neutral, since it has no specific qualitive properties which indicate from which sense the signal was original initiated. But how is the information encoded? In other words, how can the variety of our conscious experience be caused by simple inhibition and excitation of nerve cells embedded in an admittedly complex system? Because of the lack of better metaphors, the answer is often given by comparing the brain to a modern digital computer. Parsing the world into objects, making inferences, having associative memory and the like can be analyzed by developing computational models. The underlying paradigm is that the information is represented by the rate of action potential spikes. How this is exactly realized is the aim of research of biophysics, a subdiscipline of neurobiology.

In cognitive psychology, however, the methods used differ. This is because the main interest is not devoted to the organization of single neuron circuits, but rather to the larger, functional units in the network.

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Links

- PDF file of the "ethics code" of the American Psychological Association
- Cognitive Psychology miniscript by Fabian M. Suchanek
- Famous papers in the history of cognition

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2 Problem Solving from an Evolutionary Perspective

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Introduction

Gestalt psychologists approach towards problem solving was a perceptual one. That is, for them, the questions about problem solving were:

- how is a problem *represented* in a persons mind, and
- how does solving this problem involve a reorganisation or *restructuring* of this representation?

Restructuring is basically the process of arriving at a new understanding of a problem situation - changing from one representation of a problem to a (very) different one. The following story illustrates this:

Two boys of different age are playing badminton. The older one is a more skilled player, and therefore it is predictable for the outcome of usual matches who will be the winner. After some time and several defeats the younger boy finally loses interest in playing, and the older boy faces a problem.

The usual suggestions, according to M. Wertheimer (1945/82), at this point of the story range from 'offering candy' and 'playing another game' to ' not playing to full ability' and 'shaming the younger boy into playing'. And this is what the older boy comes up with:

He proposes that they should try to keep the bird in play as long as possible - and thus changing from a game of competition to one of cooperation. They'd start with easy shots and make them harder as their success increases, counting the number of consecutive hits. The proposal is happily accepted and the game is on again.

Insight

There are two very different ways of approaching a goal-oriented situation. In one an organism readily reproduces the response to the given problem from past experience. This is called *reproductive thinking*.

The second way requires something new and different to achieve the goal, prior learning is of little help here. Such *productive thinking* is (sometimes) argued to involve insight. Gestalt psychologists even state that insight problems are a separate category of problems in their own right.

Tasks that might involve insight usually have certain features - they require something new and nonobvious to be done and in most cases they are difficult enough to prevent that the initial solution attempt is successful. When solving this kind of problems one experiences a so called "AHA-experience" - the solution pops up all of the sudden. At one time they do not have the answer to a problem and in the next second it's solved.

Fixation

Sometimes, previous experience or familiarity can even make problem solving more difficult. In effect habitual directions can get in the way of finding new directions. This is called *fixation*.

Mental Fixedness

One approach to studying fixation was study wrong-answer verbal insight problems. To this, people tend to give rather an incorrect answer when failing to solve, than to give no answer at all. A typical example is, when people are told that, on a lake, the area covered by water lilies doubles every 24 hours and that it takes 60 days to cover the whole lake, and are asked: 'How many days does it take to cover half the lake?' the typical respond is '30 days' (whereas 59 days is correct).

These wrong solutions are due to an inaccurate interpretation, hence representation, of the problem. This can happen because of 'sloppiness' (a quick shallow reading of the problem and/or weak monitoring their efforts made to come to a solution). In this case error feedback should help people to reconsider the problem features, note the inadequacy of their first answer, and find the correct solution. If, however, people are truly fixated on their incorrect representation, being told the answer is wrong doesn't help. In a study made by P.I. Dallop and R.L. Dominowski in 1992 these two possibilities were contrasted. In approximately one-third of the time error feedback led to right answers, so only approximately one-third of the wrong answers were due to inadequate monitoring.

Functional Fixedness

Functional fixedness concerns the solution of object-use problems. The basic idea is that, when the usual way of using an object is emphasized, it will be far more difficult for a person to use that object in a novel manner.

Problem Solving - Modern Approaches

Problem Solving as a Search Problem

The idea of regarding to problem solving as search problems was invented by Alan Newell and Herbert Simon while trying to design computer programs which could solve certain problems. This led them to develop a program called General Problem Solver which was able to solve any well-defined problem that can be formalized like chess or the towers of hanoi, but was not able to solve any real world problem.

Any given problem consists of two special states namely an initial and a desired final or goal state. To represent all possible situations between the initial and the goal state, intermediate states were introduced. Additionally there exist a set of operators to move from one state to another. A solution is a sequence of actions describing how to reach the goal state. The simplest method to solve a problem, defined in these terms, is to search for a solution by just trying one possibility after another (also called trial and error).

As already mentioned, this method of problem solving is not capable of solving real world problems since it is usually not possible to formalize these problems in such a way that a search algorithm is able to search for a solution.

Means-End Analysis

Another way is to try to divide a problem into smaller ones by creating sub goals. This method is called means-end analysis and can be best demonstrated with the towers of hanoi problem. The initial state is a stack of discs of different sizes on a peg. There are three pegs (A, B and C) and the discs are on the left one. A disc has to be always placed on a bigger one or on an empty peg. The goal is to move the stack of disks to the right peg, but only one disc can be moved at once. The following recursive algorithm solves this problem by using the means-end analysis:

1. move n-1 discs from A to C
2. move disc #n from A to B
3. move n-1 discs from C to B

(n is the total number of discs)

With each recursive loop the problem is reduced by one.

This is an important everyday problem solving strategy - like, say, writing this chapter of the book. We describe one aspect after another to give you, the reader, an overview of the subject that is as comprehensible as possible.

Analogies

Analogies describe similar structures and interconnect them to clarify and explain certain relations. In a recent study, for example, a song that got stuck in your head is compared to an itching of the brain that can only be scratched by repeating the song over and over again.

Restructuring by Using Analogies

One special kind of restructuring, the way already mentioned during the discussion of the Gestalt approach, is *analogical problem solving*. Here, to find a solution to one problem - the so called *target problem*, an analogous solution to another problem - the *source problem*, is presented.

An example for this kind of strategy is the **radiation problem** posed by K. Duncker in 1945:

As a doctor you have to treat a patient with a malignant, inoperable tumor, buried deep inside the body. There exists a special kind of ray, which is perfectly harmless at a low intensity, but at the sufficient high intensity is able to destroy the tumor - as well as the healthy tissue on his way to it. What can be done to avoid the latter?

When this question was asked to participants in an experiment, most of them couldn't come up with the appropriate answer to the problem. Then they were told a story that went something like this:

A General wanted to capture his enemy's fortress. He gathered a large army to launch a full-scale direct attack, but then learned, that all the roads leading directly towards the fortress were blocked by mines. These roadblocks were designed in such a way, that it was possible for small groups of the fortress-owner's men to pass them safely, but every large group of men would initially set them off. Now the General figured out the following plan: He divided his troops into several smaller groups and made each of them march down a different road, timed in such a way, that the entire army would reunite exactly when reaching the fortress and could hit with full strength.

Here, the story about the General is the source problem, and the radiation problem is the target problem. The fortress is analogous to the tumor and the big army corresponds to the highly intensive ray. Consequently a small group of soldiers represents a ray at low intensity. The solution to the problem is to split the ray up, as the general did with his army, and send the now harmless rays towards the tumor from different angles in such a way that they all meet when reaching it. No healthy tissue is damaged but the tumor itself gets destroyed by the ray at its full intensity.

M. Gick and K. Holyoak presented Duncker's radiation problem to a group of participants in 1980 and 1983. Only 10 percent of them were able to solve the problem right away, 30 percent could solve it when they read the story of the general before. After given an additional hint - to use the story as help - 75 percent of them solved the problem.

With this results, Gick and Holyoak concluded, that analogical problem solving depends on three steps:

1. *Noticing* that an analogical connection exists between the source and the target problem.
2. *Mapping* corresponding parts of the two problems onto each other (fortress → tumor, army → ray, etc.)
3. *Applying* the mapping to generate a parallel solution to the target problem (using little groups of soldiers approaching from different directions → sending several weaker rays from different directions)

Next, Gick and Holyoak started looking for factors that could be helpful for the noticing and the mapping parts, for example:

Discovering the basic linking concept behind the source and the target problem.

Schema

This basic linking concept (see above) was called *problem schema*.

To activate a schema, *schema induction* is necessary.

One successful way to achieve schema induction by Gick and Holyoak: Before letting the participants solve the radiation problem the instructor gave them two stories to read, the one with the General and one with a similar outline. Now the participants were asked to write a brief summary about the similarities of these stories.

When the underlining similarities where indirectly emphasized in this way, 52 percent of the participants were able to solve the radiation problem without any hints given.

How do Experts Solve Problems?

With the term *expert* we describe someone who devotes large amounts of his or her time and energy to one specific field of interest in which he, subsequently, reaches a certain level of mastery. It should not be of a surprise that experts tend to be better in solving problems in their field than novices (people who are beginners or not as well trained in a field as experts) are. They are faster in coming up with a solution and have a higher success rate of right solutions. But what is the difference between the ways experts and nonexperts solve problems? Research on the nature of expertise has come up with the following conclusions:

- Experts **know** more about their field,
- their knowledge is **organized** differently, and
- they spend more time with **analyzing** the problem.

When it comes to problems that are situated outside the experts' field, their performance often doesn't differ from that of novices.

Knowledge:

An experiment by Chase and Simon (1973a, b) dealt with the question how well experts and novices are able to reproduce positions of chess pieces on chessboards, shown to them briefly. The results showed, that experts were far better in reproducing actual game positions, but that their performance was comparable with that of a novice when the chess pieces were arranged randomly on the board. Chase and Simon concluded, that the superiority on actual game positions was due to the ability to recognize them from the more or less 50,000 patterns stored in an expert's memory. In comparison, for a good player there may be 1,000 patterns and for a novice only few to none at all.

Organization:

In 1982, M. Chi and her co-workers took a collection of 24 physics problems and presented them to a group of physics professors, as well as to a group of students with only one semester of physics. The task was to group the problems based on their similarities.

As it turned out, the students tended to group the problems based on their *surface structure* (similarities of objects used in the problem), whereas the professors used their *deep structure* (the general physical principles) as criteria.

Analysis:

Experts often spend more time trying to understand the problem before actually trying to solve it. This way of approaching a problem may often result in what appears to be a slow start, but in the long run this strategy is much more effective.

Divergent Thinking

The term *divergent thinking* describes a way of thinking that doesn't lead to one goal, but is open - ended. Problems that are solved this way can have a large number of potential 'solutions' of which none is exactly 'right' or 'wrong', though some might be more suitable than others. It can be contrasted by *convergent thinking* - thinking that seeks to find the correct answer to a specific problem.

Divergent thinking is often associated with creativity, and it undoubtedly leads to many creative ideas. Nevertheless, researches showed that in the processes that result in original and practical inventions, things like searching for solutions, being aware of structures, and looking for analogies are also heavily involved.

The Evolutionary Perspective

In 1831 Charles Darwin began to develop the evolutionary theory which was meant to explain why there are so many different kinds of species. This theory also is important for psychology because it explains how species were designed through evolution and what their goals are. By knowing the goals of species it is possible to explain and predict behaviour.

Natural Selection

The mechanism of natural selection is the basic and most important one of which were introduced by the theory of evolution. It is this process that makes organisms with superior traits more likely to survive and reproduce. Without natural selection the growth of populations is exponential. For example an organism that reproduces once a day will create a population of about 2^{29} organisms within a month. In natural populations this is not the case and most populations are relatively stable, since most organisms do not have as many offspring as they might have. This is caused by the environment. Hence, if an individual is better at finding food or avoiding predators it is more likely that it will survive. This ability which enables the individual to survive will be passed on to the next generation. On the other hand if an individual fails to survive its disadvantages will not be passed on to the next generation. Over many generations this natural selection will lead to individuals that are better adapted to their environment. This process may also be called "reproduction of the fittest". Natural selection can only work if there are random changes in the genetic process, also called mutations. Only if these mutations are significant, natural selection can choose which version better solves the problem of "staying in the game of evolution".

As traits can only spread through reproduction, natural selection is a very slow process. The time until an individual is able to reproduce is called the generation time (approx. 20 years for humans). Evolution is such a slow process since natural selection can only choose from existing alternatives. That is, until a new trait becomes common it has to develop and spread in the whole population which of course takes much time.

Adaptation As a Result of Natural Selection

Variations in individuals are constantly tested whether they help to survive in the environment or not. This variation can be of any kind, for example an enhancement of the body or a new behaviour that enables the individual to solve certain problems which are necessary to survive or aids reproduction. These variations are called adaptations because they adapt the individual to its environment. Adaptations are structurally complex and support reproduction.

Psychological Adaptation

Evolutionary psychologists think of the mind as a modular system. This perspective on modularity was mainly developed by Leda Cosmides and John Tooby. It is based on the assumption that the mind has evolved by natural selection and therefore should solve the same problems as other organs namely survival and reproduction. Each module of our mind is responsible for one task (e.g. face recognition) and can be adapted by natural selection. So behaviour is not adapted directly but rather indirectly by modifying the underlying neuronal networks to produce adaptive behaviour.

Adaptations May Be Out-of-Date

A disadvantage of the slow evolutionary process is that when the environment changes quickly, adaptive functions and behaviour may be out-of-date. The result is that organisms are better adapted to the past and this is an important point if we think about human social behaviour and the development of cultures (see chapter Evolutionary Perspective on Social Cognitions for details).

Sexual Selection

Besides the theory of natural selection there is another one called the theory of sexual selection. It states that there is also a kind of selection between individuals of the same sex which leads to a development and spread of traits in males or females.

> Sexual selection depends on the success of certain individuals over others of the same sex, in relation to the propagation of the species; while natural selection depends on the success of both sexes, at all ages, in relation to the general conditions of life. —*Charles Darwin, 1871*

A famous example for sexual selection is the peacock. The evolution of its tail cannot be explained by natural selection only because it is neither very helpful to find food nor does it help to avoid predators, even the opposite is the case. But it makes the peacock more attractive to the opposite sex and therefore conducts to reproduction due to the fact that this oversized tail can only be worn by a male that is strong enough to wear a disadvantage.

Darwin argued that the female peahen chose to mate with the male peacock who had the most beautiful plumage in her mind (intersexual selection).

Altruism

Natural selection favours the strong and selfish who acts in his own interest. But there are other traits like altruism which are very common in human behaviour and it seems that they cannot be explained by natural selection only. With regard to a whole group traits can be characterized as

- increasing the fitness of the individual (self) or
- increasing the fitness of the group.

Altruism obviously increases the fitness of the group, but decreases the fitness of individuals what at first glance conflicts with the theory of evolution and natural selection. But there are three attempts to explain why individuals decrease their fitness for the fitness of a group, namely

1. group selection,
2. kin selection and
3. reciprocal behaviour

which will be explained in more detail in chapter Evolutionary Perspective on Social Cognitions. We will focus here on reciprocal behaviour with regard to problem solving.

Reciprocal Behaviour

Why should an individual behave altruistic if it cannot be sure whether its recipient will also behave altruistic or not? Reciprocity is one explanation for these phenomena. That is, an altruistic individual will only offer an altruistic act to an individual which is known to be altruistic and will withhold altruistic behaviour to individuals which only act selfish. This exception prevents altruists from extinction and allows them to spread in population, but it presupposes that both individuals interact more than once and that they are able to recognize each other.

We can distinguish two types of reciprocal behaviour: direct and indirect reciprocity. The direct one is an exchange of altruistic behaviour between the same two individuals ("I scratch your back and you'll scratch mine") whereas the indirect one is between different individuals ("I scratch your back and someone will scratch mine"). The latter is even more complicated to explain, but it is a fundamental trait in our contemporary society. The basic idea to explain these phenomena is the development of reputation in society. That is, altruists decide whether or not to interact with someone according to the reputation of an individual.

(Iterative) Prisoner's Dilemma

The problem of cooperation is also topic in game theory a branch of applied mathematics where players try to maximize their winnings. There are many convergences between the theory of reciprocity and game theory, one famous example is the prisoner's dilemma. Two people A and B have been captured by the police, they committed a crime but the police is not able to proof that they are guilty, but they have enough evidence to arrest them for six months. Before A and B have been captured by the police they both agreed to keep silent. At the police department they were questioned in separate rooms and both have the choice to cooperate with his partner or with the police. If one betrays the other he will get free and his partner will have to serve for ten years. If they both betray each other they will both have to serve for two years. But if both keep silent, they only have to serve for six months.

	Prisoner B

		Stays Silent	**Betrays**
Prisoner A	**Stays Silent**	Both serve six months	Prisoner A serves ten years Prisoner B goes free
	Betrays	Prisoner A goes free Prisoner B serves ten years	Both serve two years

The dilemma is that both accused people do not know how the other has decided or will decide. Regardless how the other will decide, confessing the crime will improve the outcome. If A betrays B, A will get free or he will stay in prison for two years. If he does not betray B, A will stay in prison for six months or ten years depending on however B decides. So obviously the best choice is to betray the other. There is an interesting extension of the dilemma called iterative prisoner's dilemma. The game is played again and again so it is possible to punish selfish behaviour in order to support altruism. One good strategy for the iterative prisoner's dilemma is tit-for-tat. At the first round this strategy suggests to cooperate with the partner. All other rounds one will do whatever the partner did in the round before. If someone betrays his partner, he will get punished next round. On the other hand, if someone always acts altruistic he will get paid back. This strategy is nothing but reciprocity.

Consciousness

When bringing Problem Solving and evolution together, explaining consciousness is an important point to understand how we have come this far. The answer shall be given in three steps: (1) The advantages that consciousness gave us during the evolutionary process. (2) The observations, through which neuropsychology has approached consciousness. Observations of various kinds of impairment like blindsight, commissurotomy, hemineglect, anosognosia, and also another approach called "binding problem" which tries to explain how distributed activities of neurons make up conscious perception by means of EEG monitoring. (3) Finally, what is probably the most controversial step, dealing with some suggestions of how consciousness is involved in Problem Solving, namely (psycho-)functionalism, metacognition and situation models.

Evolution of Consciousness

When trying to explain consciousness from an evolutionary perspective, there are two possible options of approach. Either you specify the function of consciousness and thus give reasons for an evolutionary progress or you explain how our abilities we gained through evolution made it inevitable to make us conscious. Furthermore, it has to be considered at what time consciousness may have appeared, that is where we can find consciousness in animals. While the first two theories presented here will give reasons for why the function of consciousness has some benefits, the third theory is more about the development of the brain that was not caused by any benefits of cognition but nevertheless enabled the emergence of consciousness.

(*direct source* [1])

As a pioneer in this field, William James (1890)[2] argued that evolution pushes the behaviour of an organism into a direction that is of interest for it. The brain was seen as an instrument to make predictions and therefore also having the ability to choose among many possibilities. So consciousness is involved in reinforcing the favourable possibilities while repressing the unfavourable. James assumes that the evolution of consciousness happened at the same time at which the cerebrum had evolved. It allowed to selectively guide the nervous system in an environment that became more and more complex throughout evolution (1890/1891, p. 147)[2].

James distinguishes three classes of animal consciousness. The first class contains bilateral invertebrates (earthworms, leeches, spiders, and insects) that show a centralisation of the nervous system. The main criterion for this class is the differentiation between having a sensation and not having that particular sensation. Although this can only be considered as a primitive mental state, the detection of stimuli is thought to be a condition for consciousness. An example of scientific investigation was done by Keunzi and Carew (1991)[3] showing that the marine snail Aplysia californica reacted differently to light from various directions and could also be trained to behave in a certain way through conditioning.

The second class contains animals that do not only remember previous experiences but are also capable of equate them with present experiences. They are able to copy a model or in other words imitate a behaviour which is regarded as the beginning of conceptual thought. Here the animal class of cephalopods should be mentioned. Octopus vulgaris which belongs to this class was examined by Fiorito and Scotto (1992)[4]. They separated the octopuses into the "demonstrator" and "observer" group. The "demonstrator" group was trained with conditioning techniques to attack either a white or a red ball when offered both. Then an octopus of the "observer" group watched an octopus from the "demonstrator" group attacking a ball with the specific colour. The "observers" imitated the attacking behaviour rapidly, however they sometimes chose the ball with the respective other colour. Because of this choice, it is assumed that a primitive form of consciousness is involved.

The third class entails humans as well as great-apes (gorillas, orang-utans, chimpanzees) and cetaceans (whales, dolphins). In comparison to other animals they all possess a larger surface area of the cerebrum, the neocortex. The main feature of this class is the capability of self-consciousness which is according to James a more complex form. Gallup (1970)[5] introduced an experiment to find out whether animals or infants are able to distinguish "me" from "not me". Red dye is put on the forehead that can not be recognized except with the aid of a mirror. However, it is in question whether this method can be seen as a test for self-consciousness in the sense that there is an awareness of one's own thoughts.

These three classes were shortly presented because later, in the third part of the subtopic of consciousness, we will introduce a general definition for consciousness which will give us a different but quite similar classification and a suggestion of how to overcome this last problem.

(*Blackmore, S. J., 2004* [6])

Another theory that contributes to the idea of consciousness having a function is held by Nicholas Humphrey. The main thesis is that consciousness has a social function. While animals like chimpanzees live in a social environment, humans are highly specialized to social skills. Humphrey believes that skills like understanding, predicting and manipulating the behaviour of others became necessary for our ancestors because, in a group, they were facing situations like deciding whether a group member is a friend or an enemy or when they should form alliances etc. He calls our ancestors having evolved this way "natural scientists".

How consciousness could have had influenced this can be shown by considering the following

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