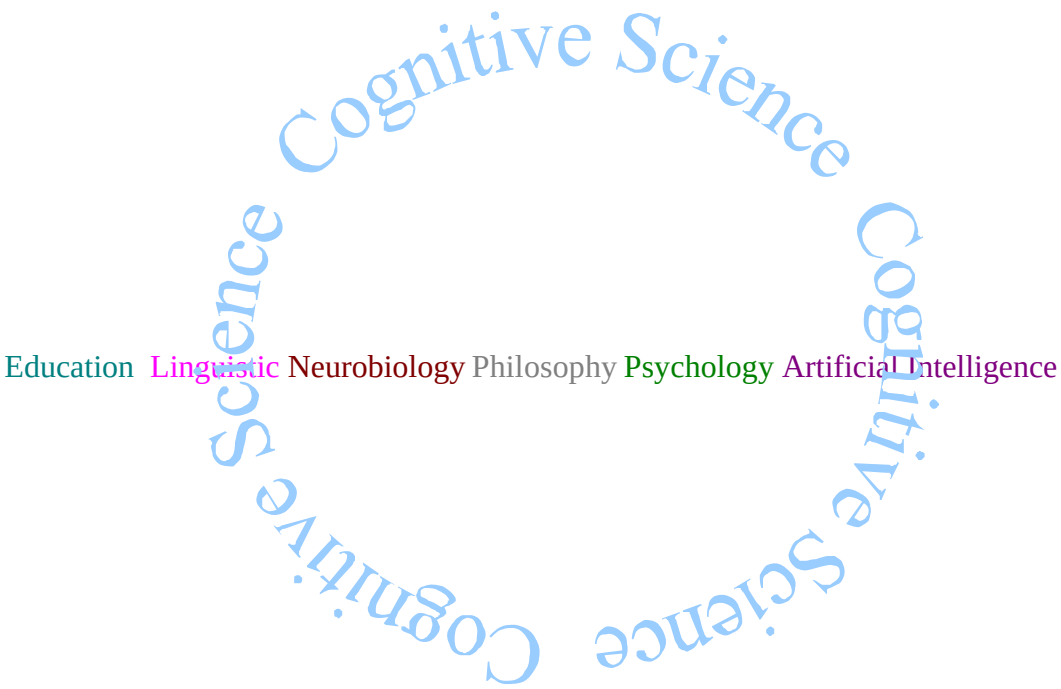
The Concept of Intelligence in Cognitive Science



Name: Gabriele Schön

Assignment 1

Literature Review

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Introduction

"Intelligence surrounds us."

Module: Computer Applications in Education

Module Code: CA 564

Module Aims: The module is designed to enable the participant to:

1. examine the development of the use of information technologies in education in the broader context of current educational theory and practice
2. implement and evaluate computer applications and media in a range of curriculum areas
3. examine the potential for improving the impact of information technologies in school through research and curriculum development

Learning Outcomes:

As a result of this module participants will be able to

- understand the principal concepts of educational computing
- analyse and evaluate computer applications in education
- evaluate the role of hypermedia and the Internet in schools education
- review research and development in computers in school

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Intelligence surrounds us, Luger claims in his introduction to "Cognitive science"(1995, ix). It is present all the time, more than the occurrence of artistic and creative brilliance, present in the moment-to-moment adaptation of systems to complex environments, in the recognition of patterns, and even in the retrieval of old memories. It seems to me that even in the outlines of the modules and their aims it is implicit. As a student of Computer Applications for Education I am required to take the above mentioned modules and to reach the stated goals of the course.[1] What enables us to understand these concepts mentioned in the outlines and on which assumptions do we think we can pass on knowledge to others? Is it our verbal ability, language, ability to deal with abstract concepts, knowledge, motivation – in general 'intelligence'? Why do students perceive the content and the way it is dealt with differently? Why do some people

[1] When evaluating various software products or web sites in class, it quickly became apparent that different concepts of 'intelligence' exist. Looking at software products which claim to be intelligent tutoring systems I realised that there is a different concept behind it which does not match my concept of 'intelligence' in the field of second language acquisition. The concept of intelligence, therefore, might have an impact on the readiness of teachers to use so called 'intelligent' systems in class or not.

pass, while others fail? And, as one of the module aims is to evaluate computer applications – what, for example, is 'intelligent' about an intelligent tutoring system? Is my watch intelligent?

The concept of "intelligence" seems to be a broad field which has occupied many researchers for years without their reaching definite conclusions. On the other hand it is a concept with we are confronted on a daily basis and which we operationalise in a relatively concrete manner. A teacher, for example, might talk about a very intelligent or a less talented student. Even some idioms refer to intelligence, e.g " Man kann von einem .Pott nicht mehr erwarten als von einem Kessel."
According to Luger the field of Cognitive Science is dedicated to finding the common set of principles underlying all instances of intelligence (ibid., 4). Cognitive Science thus is a interdisciplinary field, including disciplines like Psychology, Neurobiology, Philosophy, Linguistics, Artificial Intelligence, Computer Science, Education.

In this assignment I will look at the various literature in the area of cognitive science to see which concepts of intelligence are proposed. This can only be a glimpse into the literature about intelligence. I am fully aware of how broad this topic is, but in studying some of the literature on Cognitive Science, I hope to get a clearer understanding of this area. The authors chosen are representatives of different approaches to get a first impression of the subject area.

1. Literature Review

Intelligence and Education

In the introduction, it was asked how it is possible to learn and pass knowledge on to others. In the book "The Teaching of Thinking", Nickerson et al. (1985) describe intelligence from a paedagogical point of view as a multi-faceted concept which manifests itself in many ways. People considered intelligent are likely to give evidence of possessing a variety of intellectual skills. The authors try to describe these intellectual skills in an intuitive, additive way by listing up abilities which represent some of the functions of what an intelligent organism or artefact is able to perform. Six features are in their view definitely connected to the label 'intelligent':

- The ability to classify patterns
- The ability to modify behaviour adaptively through learning

- The ability to reason deductively
- The ability to reason inductively
- The ability to develop and use conceptual skills
- The ability to understand

These abilities enable people to perceive the world around them: they enable them to process information as kind of a Knowledge Processing through categorising it, drawing inductive or deductive conclusions from situations to build up concepts (induction) about the world which help to understand and create reality (deduction). The conclusions about reality might not always be right, and thus also artificially intelligent machines do not always need to be right, but there has to be a certain consistency.

Adaptation, induction and deduction form the central aspects of intelligence as they represent the three fundamental forms of logic (claimed by Pierce (1935), discussed in Nickerson (1985, 24)). Adaptation works on the basis of one's experience to be more effective in coping with one's environment. It implies that behaviour can be changed and that there is room for creativity in changing these behavioural patterns. Deduction describes the ability to draw logical conclusions from premises, the inferring of particular instances from a general law, and conversely induction describes the inference of a general law from particular instances. They are vital for perception of the world as they enable organisms to "know" more about the world than is explicitly learned or to go beyond information at hand.[2]

The idea that intelligence is a multi-faceted concept is shared by many scientists, though they differ widely in the number of abilities or facets responsible for intelligence.[3] However, drawing up factors important to intelligence – the so-called factor-oriented approach – in the authors experience does not help to explain why there are degrees of intelligence in people. They criticise the fact that intelligence has only a relative ethno- or egocentric value and the model of intellect is a heuristic device of researchers:

"In my opinion, then, intelligent person is a prototype-organised Roschian concept. Our confidence that a person deserves to be called 'intelligent' depends on that person's overall similarity to an imagined prototype, just as our confidence that an object is to be called 'chair' depends on it's similarity to prototypical chairs. There are no definite

[2] The ability to understand is only vaguely described by the authors, they claim that understanding is vital for receiving information, and that there is a common sense of what understanding is as "we all know when we understand – or think we understand – something." (Nickerson (1985, 12))
[3] In fact, all the literature reviewed shares this opinion. Guilford (1967) differentiates between 120 different factors, Thurstone (1924) for example only between 6. (discussed in Nickerson et al. (1985, 16))

criteria of intelligence, just as there none for chairness; it is a fuzzy edged concept to which many features are relevant. Two people may both be quite intelligent and yet have very few traits in common – they resemble the prototype along different dimensions. Thus, there is no such quality as intelligence, any more than there is such thing as chairness . Resemblance is an external fact and not an internal essence. There can be both process-based definition of intelligence, because it is not a unary quality. It is a resemblance between two individuals, one real and the other prototypical. (Nickerson et al (1985, 17))

Here, instead of looking at intelligence as a result depending on the presence or absence of factors the relation between intelligence and cognitive skills becomes important. The relation to knowledge, thinking skills and cognitive development make the concept of intelligence dynamic and valuable in an educational setting. For example, in association with Piaget and his distinction between formal and concrete reasoning they claim that a person's level of cognitive development represents a constraint of what people can learn or not. Improving the cognitive skills means improving the overall performance. This again will have an impact on the intellectual skills of a person. The authors conclude, therefore, that intelligence and thinking are closely related, and by improving thinking skills the development of intelligence can be nurtured.

Generally, the fact that they talk about intellectual as well as cognitive skills indicates that they do not have a genetic understanding of intelligence. Rather, the relation between cognitive skills and knowledge becomes important.[4] It indicates that there are tools for reasoning which can be maximised through learning and training. Intelligence, therefore, is seen as a potential subject to development.

Intelligence and Psychology

Sternberg (1985, 1987)[5] regards the concept of intelligence to be a most elusive one similar to Nickerson et al. He also regards intelligence to be a dynamic concept. This concept in his opinion though can be described using information-processing theory of the nature of human intelligence and has to be viewed in terms of mental processes which contribute to 'cognitive task performance'.[6] Relevant therefore is not the question about how well somebody performed but which factors and mental processes contribute to successful performance. Sternberg

[4] A genetic view on intelligence was brought to my attention by a medical student once who claimed that intelligence has to be measured before the age of 9/10 as the gain of knowledge becomes predominant after that.
[5] Sternberg further develops his theories in his 1995 publication which is, however, unavailable to me at this point in time.
[6] The notion of an information-processing system is closely related to the Turing notion of a universal machine.

developed a triarchic model of intelligence according to which three different aspects of human information processing should be examined in relation to

- the structures and processes that are inherent to intelligent behaviour, addressing the mechanism of intelligent functioning,
- the application of these structures to the problem of reaching certain aims in the external world,
- the role of experience in forming intelligence and it's application.

The behaviour underlying the structures and processes are again divided into three categories:

- the metacomponents, deciding on the nature of a problem and selection of a strategy to solve it, which represents high-level management of problem-solving
- performance components, which are processes used to actually execute a problem-solving strategy and
- knowledge acquisition components, which are processes used to acquire new information.

According to Sternberg, the factor-analytic approach has so far only looked at the first aspect of the triarchic model in trying to find criteria for intelligence and looking at the presence or absence of these criteria in a person in order to measure the level of intelligence. He criticises their result-oriented focus on accuracy rather than process as it does not provide an insight into the potential of intelligence. Hence, it needs supplementation. Abilities should be examined with regard to the underlying mechanisms they represent.[7] It becomes apparent that for Sternberg intelligence has a modular character on different levels. The dynamic concept is therefore stronger than the work surface for forming and changing intelligence and it's applications are also accounted for. In including the role of experience and knowledge in his model, intelligence per se is a development process and thus can be subject to changes. Furthermore, including the aspect of 'application' underlines the fact that different strategies in using these structures lead to different 'intelligent' behaviour. Looking at the different levels in order to find the connection provides a better opportunity to actually understand and enhance (human) intelligence which is – according to Luger (1995) – after all the goal of Cognitive Science. Sternberg goes even a bit further as he incorporates a functional-pragmatic aspect into his concept of intelligence:

[7] Attempting to explore what actually happens when certain skills are executed rather than asking about the outcome can be observed in many different disciplines. In translation studies, for example, one of the attempts to get new information on how translation actually works is through Think Aloud Protocols which try to get an insight into the actual process by listening to the comments of the translators while translating.

"Intelligent thought is directed toward one or more of three behavioural goals: adaptation to an environment, shaping of an environment or selection of an environment. These three goals may be viewed as the functions toward which intelligence is directed: Intelligence is not aimless or random mental activity that happens to involve certain components of information processing at certain levels of experience. Rather, it is purposefully directed toward the pursuit of these three global goals, all of which have more specific and concrete instantiations in people's lives."(Sternberg (1987, 158))

Therefore, intelligence or better 'intelligent thought' does not exist per se but is used as a 'tool' towards the fulfilment of specific aims.[8] This functional-pragmatic description of intelligence is open towards any specific culture or species even though he talks mainly about "people's lives". It can be applied to all levels of intelligent behaviour and thus puts the concept of intelligence into a broader frame.

Sternberg and Nickerson agree in a lot of aspects except the functional perspective. Also, adaptation is in the centre of Sternberg's concept which is therefore not necessarily anthropocentric. (more computational, complex process to be reduced to it's basic components)

Intelligence and Verbal Ability

In Sternberg's opinion the abilities forming intelligence should be looked at in regard to their functioning, e.g. the verbal, reading, second-language, mathematical, problem-solving ability etc. One of Sternberg's scholars, Hunt (1985), describes in his essay the verbal processes that contribute to cognitive task performance. Verbal ability is looked upon by most people as a given fact: "... for verbal intelligence, though, there is objective evidence that this ability exists." (Hunt (1985, 32)) But what are the factors, which combine to form 'verbal intelligence'? Hunt tries to split 'verbal ability' up into it's sub-abilities to see how many various language-related abilities exist, and how these abilities might account for differences in 'general verbal ability'. (Sub-)Abilities thus are components of a of higher level ability. Areas which he states are of importance to comprehension of language are lexical access, comprehension of isolated sentences and expressions, comprehension of connected discourse and allocation of attention in comprehension. In each area the performance of one individual might differ from another. Therefore, sub-abilities have to be differentiated from skill performance. In the simplest case,

[8] Again, this concept of looking at intelligence as a tool emphasises the modular character of intelligence. Language could be subsumed under the heading of 'cognitive task performance' but is also looked upon as a tool for achieving specific aims. This will be become apparent in the article by Hunt (1985) who looks at the processes involved in verbal ability.

there might be a direct, linear relation between an underlying ability and a complex skill: the greater the ability, the more proficient the skill performance. In other cases, the relation might be more complex. Hunt states that it might be that an ability must be present in some degree in order to produce adequate performance, but superior ability may not guarantee superior performance in the more complex task as other factors come into play.[9] He supports his statements with tests on the performance in the sub-abilities and examines the correlation with test results on the higher level which were factum.

He concludes that comprehension is a complex process, composed of many sub-processes, which range from automatic, involuntary acts of lexical identification to planned strategies for text comprehension.[10] The individual differences in all these sub-processes combine to produce individual verbal intelligence. As valid as this observation is – it includes, for example, knowledge, application strategies, mental processes –, in my view, the method Hunt chooses is not that different from that of a factor-oriented approach. This approach, according to Sternberg, did not deny the fact that there are different aspects of intelligent behaviour, and they also tried to describe and measured the degree of presence or absence of these certain aspects to get an overall picture. Hunt uses the same method to get to his results only he looks at classes of abilities like in a tree-structure testing performance on each level.[11] The understanding of intelligence is still an additive one although the skills might not be of equal importance. In addition to that, the jungle of vaguely defined terms make it difficult to follow his concept. What is verbal intelligence in regard to verbal ability or general verbal ability and intelligence as well as comprehension skills?[12]

Intelligence and Artificial Intelligence

A particularly mathematical approach to Cognitive Science and intelligence is taken by Goertzel (1993). The aim of cognitive science, according to Goertzel, is the analysis of mental processes in terms of simple procedures as they are easily programmable. In his view,

[9] See Hunt (1985, 35)

[10] It seems to me this perspective tries to reinvent the wheel as the insight that communication and language comprehension involve complex mental processes is hardly new. Also, I am not convinced that splitting up the abilities – here the comprehension process – into comprehension of smaller categories – comprehension of contextless sentence, phrases, words – describes the process of comprehension accurately.

[11] Interestingly, he claims that there is a correlation between knowledge acquisition and verbal ability. This statement is based on the observation of test results, namely that the higher students scored on verbal ability tests, the higher they also scored in knowledge tests. The correlation between the scores supports the result on the higher level.

psychology and philosophy have not yet found a valid answer to the question of what intelligence is and how the mind is structured. In agreement with Sternberg and Nickerson et al. he claims that the theories on intelligence are not theories of the same thing but represent different aspects of it. Yet the key to understanding the mind – so Goertzel says – cannot be found in contemporary psychology but in a new field called "complex systems science" which is based on the idea that "complex systems are systems which – like immune systems, ecosystems, societies, bodies and minds – have the capacity to organise themselves." (Goertzel (1993, 3) The mind as a self-organising system is highly organised and based on interacting algorithms or automata.

In regard to complex systems, intelligence is defined as the ability to optimise complex functions of unpredictable environments. This definition already includes aspects of capacity to learn as a basic intellectual ability, but to be able to simulate this ability using computers still represents a problem. One way to cater for a certain flexibility is the concept of a "stochastic" computer. Such a computer is subject to random errors, due to certain mathematical rules. While Nickerson (1985) claims that intelligent computers do not need to be completely error proof because also humans, too, form wrong conclusions which sometimes have to be altered, Goertzel looks at the other side, the potential implicit in errors for learning.

Goertzels aim is to find a precise, general mathematical definition of intelligence which is objective in the sense that it does not refer to any particular culture, species, etc. The leading question is how intelligence can be quantified. In looking for an answer he refers to Sternbergs triarchic model as it, in his view, seeks to understand the interconnections between structures and processes underlying intelligent behaviour, the applications of these structures to problems in order to attain goals in the external world and the moulding of intelligence by experience. In his opinion even though he does not see similarities to his idea, it represents a useful "network" and relates abstract mathematics to contemporary psychological research. This idea of a network forms the basis of his attempt to find the universal structures underlying intelligent behaviour, and brain and mind are in his view networks of programs or networks of automata.[13] The model he suggests is reminiscent of Chomsky's language philosophy and his effort to find

[12] I do not want to indicate in any way that I do not value Hunt's analysis. Looking at the concept of intelligence and the processes underlying intelligent behaviour is useful as they help to understand how decisions are made and conclusions are drawn, how people cope and adapt, and how skills can be improved.
[13] Goetzer (1993, 21)

universal structure which is moulded into a language specific one by learning/emphasising specific connections.[14]

As mentioned before, he sees the main feature of intelligence as the ability to behave appropriately under unpredictable conditions.[15] As his aim is to describe universal structures for intelligent behaviour he has to define appropriateness and unpredictability precisely as they are only very elusive or relative concepts. He achieves this by defining unpredictability mathematically through creating a discrete system which allows unpredictability on the basis of probability- and average-calculations. He calculates different unpredictability of structure in describing the sensitivity of the discrete system under various conditions. This mathematically defined sensitivity measures process and is in his view directly related to social, psychological and biological situations as recognising patterns in a system can tell about it's future.

Appropriateness on the other hand is described as a optimisation problem, as "the ability to maximise A under unpredictable conditions." (Goertzer (1993, 65)) This leads to the working – contextual – definition of intelligence:

"Relative to some computable set of patterns C, a system S processes S.-intelligence to a degree equal to the maximum over all A of the product [S.-intelligence of S with respect to A, relative to C]*[computational complexity of optimising A]. L.,R.S. and S.S.-intelligence may be defined similarly." (ibid.)[16]

Having defined intelligence, he tries to define other aspects of intelligence, the main ones being analogy, induction and deduction. Areas of intelligent behaviour he examines are, for example, short-term memory, language-processing, vision processing, etc. His final goal is to create a master network which is a vast, self-organising network of self-organising structures, continually updating and restructuring each other. He himself admits that right now his concept is just a model of mind and lacks proof as there is no method yet which could do so. He concludes therefore with the prospect of proving it at some stage when "someone constructs as apparently intelligent machine, or until neuroscientists are able to derive the overall structure of the brain from the microscopic equations." (ibid, 164)

[14] See Chomsky (1977). Goertzer claims that a machine equipped with certain computational rules and also connectivity similar to the human brain "would be able to learn it roughly the same way as an human infant" (Goertzer (1993, 166)

[15] Goetzer (1993, 61) This definition is derived from observations of existing 'intelligent' machines that can only 'think' within their one context but cannot deal with situations in which the context is slightly different. Thus, they cannot deal with simple tasks every human being or animal can execute easily.

[16] S.-sensitivity , L.- sensitivity, R.S.- sensitivity and S.S. sensitivity are structural sensitivity, Liapunow sensitivity , reverse structural sensitivity, structural-structural sensitivity. The definition is difficult to relate to and is given as an illustration of his method. He explains that for to measure the sensitivities the average of the respective sensitivities at all points x of X has to be measured.

The concept of Goertzer is difficult to consider as it withdraws from any kind of direct proof. The aspects he sees as relevant for intelligence are similar to those of the other authors. His emphasis on the fact that intelligent behaviour is executed especially in unpredictable situations is very interesting though, his critic of current machines understandable if one shares his premises that it is possible to develop a universal structure for intelligence. He tries to reduce the elusive problem 'intelligence' to it's core features, and in defining them he recursively tries to define the other layers to be thus able to computationally build up a network of algorithms. Also, it allows intelligence to be a nonbiased concept.

Intelligence and Artificial Intelligence

In his book "Comparative Approach to cognitive Science" Roitblat (1995) tries to put intelligence back onto a level where it is regarded as a feature for beings in general, not only human beings similar to Goertzer. The traditional approach, he argues, has primarily an ethno- and anthropocentric outlook on intelligence as it only focuses on high-level-achievements of intelligence ignoring the more basic ones shared by other organisms. Also, language ability is overemphasised by considering it as a defined feature of human cognition and intelligence which lead to the domination of a computational approach according to which cognition is symbolic computation.[17] This results in machines which are 'blinkered idiots' as they focus only on processing symbols of a predefined kind and neglect how these symbols relate to the environment.

Therefore, he draws an important distinction between cognitive science, as it has traditionally been implemented via serial processors following implicitly designed rules (Turing-machine), and what he calls a biomimetic approach. Such an approach is based on connectionist principles and constraint satisfaction. In Roitblat's opinion a lot can be learned from examining the mechanisms used by other species. He claims that quite a lot of everyday behaviour even though technologically rather mundane, appears on closer examination quite sophisticated. These fairly basic processes, e.g. perception, form the basis of processes constraints and support the operations of the 'higher cognitive functions'. Roitblat argues with evolution. The "evolutionary continuity suggests that a substantial part of intelligence both human and non-human is mediated by substantially different mechanisms."(Roitblat (1995, 15) The important features of

[17] See Roitblat (1995, 15)

intelligence in the context of evolutionary continuity are adaptation and constraint satisfaction, the latter defining cognition, while adaptation represents the flexibility and creativity of a system which provides efficiency in the respective environment. Constraint satisfaction implies that a system chooses between alternative hypotheses (e.g. different people) until it finds the one that best satisfies the constraints (features of face) provided by the evidence (face) and the relations amongst the hypotheses. This concept of intelligence is closely related to a connectionist model. This connectionist model is a network of neurons whereby the connections represent the constraints and associations amongst the hypotheses and the input. The strength of the association decides which hypotheses is satisfactory. The ultimate aim of Roitblat is to compare different organisms with each other to get data about the neural processes and thereby insight into the fundamental cognitive processes. He concludes:

"Because the constraints are implemented as connections among neurons the implementation of the system cannot be separated from the computations of the system. In contrast, because the Turing machine is defined relative to the computations it performs and because it can be programmed by symbols represented to it, all Turing machines are computationally equivalent to one another." (ibid, 23)

Roitblat has a modular approach to intelligence but regards it as a potential special to each species. Intelligence thus incorporates mechanisms which are connected with optimisation of living conditions regarding a specific environmental setting. On the one hand stressing the importance of appropriate behaviour in a changing environment as well as his criticism recalls very much the ideas of Goetzer, however, their approach is very different. The main feature, which plays an important role in intelligence represents in Roitblats opinion the ability to adapt to certain environments while Goetzer, having a human centred perspective, claims that the fact that an entity, e.g. a cockroach, is well adapted to it's environment does not imply that it is intelligent. Also, the 'biomimetic' model of a neuronal network where sensors provide stimuli similar to a real environment and associations between patterns of neural conditions form the basis for decision differs from Goetzers mathematical symbol-based model where even emotions are calculable. Still, both scientists have a computer-based approach as they want to build networks of respective artefacts which simulate mental processes.[18]

[18] The concept of neural network and constraint satisfaction might be compared to a pattern of pixels each of which having a state. Constraint satisfaction is based on association or the matching of patterns of neuronal conditions of the system at a time.

Intelligence and Neurobiology

An interesting contribution to the discussion is made by Roth (1996) in his book "Das Gehirn und seine Wirklichkeit" (The Brain and it's reality). In contrast to the other theories presented, the author approaches the area of cognitive science by avoiding the qualifying term 'intelligence' and it's definition and by relying on the concepts of 'mind' and 'cognition'. Intelligence for him is only a subjective criterion evaluating the behaviour of others. In contrast to that cognition represents the phenomena of powers of cognition, like perception, thinking, understanding and judging, factors which are all connected to the orientation of a organism in it's environment as the basis of adaptive behaviour. He claims that 'the mind' does not exist. Instead a multitude of different mental and psychological conditions exist. The experiencing ego, the self-conscious mind is a multi-faceted construct, not a solitary phenomenon. Therefore, it cannot be 'defined'.

Basically, Roth sees cognition as a function securing survival. His understanding of cognition – like the other cognitive scientists' – is marked by contrast towards behaviourist concepts pointing out that the relation between stimulus and response is influenced by intervening variables. These variables might be inner conditions like knowledge, attention, expectations, strategies for action, models of reality etc. However, the computational approach also has it's problems. He criticises the notion of cognition whereby it is described as symbol processing of logical syntactic structures. This approach values only humans as well as artefacts as intelligent excluding animals. This restriction of the concept to human interest is not at all justified. The brain function and neurobiological design of human beings per se do not differ from those of other creatures, the uniqueness in the productive capacity of humans being rather a combinatory effect of biological features and language. On the other hand, the neuronal concept of cognition does not withstand close examination either. If either state of condition/Erregungszustand were to be 'cognitive', e.g. the absorption of light, everything about a neuronal system would be cognitive and thus the term without any consequences. Therefore, the dividing line between cognitive and non-cognitive, which might be difficult to draw, has to be looked at. Finally, Roth concludes that cognition is based on or arises from non-cognitive processes but includes complex achievements as well, seen as typically human cognition. He differentiates between primarily physiological processes, neuronal processes between units of cells, precognitive processes like colour recognition, and cognitive, meaningful processes. The latter includes, for example, processes which resemble those Nickerson et al. and Sternberg described, such as deduction, induction, or concept-building. This is his working definition, a

kind of 4-layer-model, which is said not to be wholly satisfying but nor reductionistic either. He does not claim to have found a wholly satisfying answer yet he wants to find a work definition which is not that reductionistic like some of the dominating computational, anthropocentric approaches.

2. Conclusion

'To cut a long story short' – there is no definitive answer to the question of what intelligence is due to the multitude of elements which constitute this phenomenon and it's conceptualisation for different scientific approaches. The theories presented mirror different aspects of it depending on the focus taken. Thus, they are living proof of the belief that there is not one theory of intelligence but theories of it's aspects.
However, in my view the multi-faceted nature of intelligence partly forces a reduction to aspects in order to analyse facets and enhance understanding. In contrast to Roth, in my view, the method of reducing the phenomenon 'intelligence' to some of it's components is not per se wrong but the use of the concept to represent a particular aspect which turns qualification into judgement. Here, it is to argue with evolution like Roitblat did. In general, the interdisciplinary approach within Cognitive Science is in my view very interesting as the different facets are looked at from different perspectives. Thus, the phenomenon cannot be defined but can be described in order to evoke a more detailled image than a definition would be able to do. Contextual relationships are then isolated and considered in more depth at least to a certain extent.[19]

Interestingly enough, it seems that none of the authors, even Roth who tries to avoid the term 'intelligence', or Sternberg who sees adaptation as the main feature of intelligence, can avoid intuitively attributing some qualifying notion to 'cognition' or 'intelligence', such as higher versus lower level achievements, non-cognitive versus cognitive versus meaningful etc. This leads back to the introduction to this review where it was stated that there is a notion of intelligence present everywhere, be it conscious or unconscious. Sternberg (1985) describes in the introductory part of his article that laypersons' concept of intelligence did not differ much from those of experts'. Important in this context is, in my view, that the nature of these concept as working definitions be borne in mind. The multi-faceted concept should not be forced into a

[19] Such an approach is reminiscent to Barthes Schreibweise in his book "Am Nullpunkt der Literatur".

mould as this would fail to value the variety of life and forms existing. With regard to the question about the intelligence of, for example, tutoring systems, the consequence is rather interesting. Having stated that each concept has been looked at in regard to their approach then tutoring systems can be intelligent, for example, in fulfilling a given task highly efficient, accurate, fast – criteria used to describe the most efficient algorithms within it's field.

Still, the answer given is a non-answer at the same time. Thus, the conclusion returns to the questions posed in the introduction. If there is no definite answer and the (individual) concept is a relative one, then on the basis of which underlying – for cognitive science generally a constructivist – rationales is it formed? For teaching, it is relevant as it has a major influence on the teaching method and evaluation approach used.[20]

[20] Also, from another point of view this assignment feeds back to the beginning. As stated in the introduction, the assignment was supposed to cast a first glimpse into the area of cognitive science. Having read literature in this area some of the literature reviewed should perhaps have been omitted (e.g. Hunt) while others deserve to be included like Fodor, Newell and Anderson, Pinker (Cognitive Science and Language Acquisition). Those included, nevertheless, represent a selection of those who have helped to shape this ever changing field. However, some of the most recent publications of those researchers who were included, had to be omitted due to lack of availability.

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