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The Stage of Cognitive Science from the Perspective of Thomas Kuhn's Theory of Science

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Introduction

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Science is constantly growing and is our most reliable source of knowledge in modern society. The last several decades have been a revolutionary time in the history of science as the study of the human mind began. Science can be defined as a way of understanding the natural world and the phenomena within, using scientific methods such as experimental investigation or theoretical explanation, which are empirically testable (Scott, 2015). The physicist and historian of science Thomas S. Kuhn (1970) presented three stages of science; pre-science, normal science, and revolutionary science. In this paper, I will consider which scientific stage I believe cognitive science is in from the perspective of Kuhn's theory. Before arguing, it is important to understand the history of science and the field of cognitive science. Cognitive science can be defined as an interdisciplinary study of the human mind including knowledge from fields such as neuroscience, linguistics, philosophy, anthropology, psychology, and computer science.

In this paper, I will argue that cognitive science is in the beginning of the revolutionary stage from the perspective of Thomas Kuhn's theory of science. Firstly, I will present the history of science, following a description of Kuhn's theory of science. Afterwards I will discuss whether cognitive science is a science, and argue that computationalism has been the dominating paradigm within cognitive science. Finally, I will argue that cognitive science is in the beginning of the revolutionary stage and suggest embodied cognition to be the next dominating paradigm.

History of Science

Debates and speculations regarding human cognition can be traced to Plato and Aristotle having philosophical discussions in the ancient Greece (Anderson, 2015). The discussions developed into a centuries-long debate between empiricism, believing all knowledge comes from experience, and nativism, stating that children are born with a certain amount of innate knowledge. This debate, which started out philosophically, frequently developed into psychological speculations about human cognition. In 1879, the German psychologist William Wundt started studying the human mind and behavior with the basic assumption that the mind should be open to self-observation; a method known as introspection (Friedenberg & Silverman, 2006). The introspective idea was not well accepted in America, and it frequently became clear that much of what was important in cognitive functioning was not open to conscious experience. The behaviorist revolution in American psychology was created based on these dominant beliefs (Anderson, 2015). The behaviorist John Watson (1930) emphasized the irrelevance of consciousness:

> Possible the easiest way to bring out the contrast between the old psychology and the new is to say that all schools of psychology except that of behaviorism claim that "*consciousness" is the subject matter of psychology.* Behaviorism, on the contrary, holds that the subject matter of human psychology is the *behavior or activities of the human being.* Behaviorism claims that 'consciousness' is neither a definable nor a usable concept. (Watson, 1930, p. 3, original italics)

Watson defined behaviorism only to be concerned with external processes, and not internal, as consciousness was an undefinable and unimportant concept with no importance of human psychology. It became clear that behaviorism started to be the dominant paradigm in America in the first half of the 20th century, rejecting all theories of internal processes.

Behaviorism's position as the dominant paradigm changed between 1950 and 1970, when the cognitive revolution began and brought the study of the human mind back into experimental psychology (Anderson, 2015). The development of computer science, particularly artificial intelligence, which I will define as the science of creating intelligence into computer programs, influenced cognitive psychology. Cognitive psychology can be defined as the study of the cognitive mechanisms (Neisser, 2014). To understand cognitive psychology, a definition of cognitive mechanisms, or cognition, is needed. Cognition refers to the internal processes which store, recover, and use external sensory input. These processes include perception, attention, memory, problem-solving, sensation, imaging, and so forth. This suggests that cognition is involved in everything humans do.

In 1950, the Turing Test was developed by the computer scientist Alan Turing (Turing, 1950). The development of the test caused a greater focus on the mind and mental states in computation as the philosophical question "Can a machine think?", as Turing put it, came to attention. The development within computer science led cognitive psychology to a greater understanding of human's internal processes, intelligence, and behavior, since it suddenly was possible to model intelligent behavior of a machine (Neisser, 2014). This development of computer science led to the conception of computationalism, as computers were used to simulate cognitive processes and multiple studies regarding the mind, cognitive strategies, and componential analysis were published (Miller, 2003). Computationalism can be defined as committed to the claim that the mind is a computing system and internal processes are computational states.

The psychologist George A. Miller (2003) set the date of the conception of cognitive science to be 11th of September 1956, and emphasized that by 1960 it was clear that an interdisciplinary study, containing philosophy, linguistics, psychology, neuroscience, computer science, and anthropology, would develop. I will argue that the previously dominating paradigm of cognitive science was computationalism with the common view that the mind is a computing system and internal processes are computational states, but that we are in the early part of the revolutionary stage.

Thomas Kuhn's Theory of Science

Thomas S. Kuhn published a book in 1970 challenging the common way of understanding the development of science. The development of science was generally seen as linear, where Kuhn on the contrary presented the development of science as proceeding in stages. Kuhn's stages are as follows: pre-science, normal science, and revolutionary science. He characterizes pre-science as a stage, in which an overall paradigm, defined as an overarching world view guiding the methodological approach and interpretation of results, has not yet been found (Kuhn & Hawkins, 1963). He presents normal science as a stage, in which an overall paradigm has been found, and scientists use what he calls puzzle solving to solve most scientific work. This means that Kuhn believes scientists within a given field are fitting pieces together in consensus with the accepted paradigm and hereby do not challenge the overall paradigm. Furthermore, he explains that most scientists spend almost all their time in the stage of normal science, and rest on the assumption that the scientific community knows what the world is like (Kuhn & Hawkins, 1963). Additionally, he states that within such science, anomalies, which do not fit the accepted paradigm, will occur.

Kuhn (1970) emphasizes that at some point the multiple anomalies might lead to scientific discoveries opposing the current paradigm or develop into entirely new theories and move into the revolutionary stage. The revolutionary stage occurs when a paradigm shift happens, and the emergence of a new theory or paradigm introduces new tools, new problems, and the decision to reject older paradigms. The general world view will change due to such a revolution, as the way humans interpret objects, facts, and problems will be affected by the paradigm shift. Even though the old paradigm is rejected in a paradigm shift, all theories from this paradigm do not have to be rejected. It is possible not to rule out everything from the old paradigm, but bring some of the thoughts along into the new paradigm. The common interpretation of Kuhn's theory is to interpret the stages as a circle, where all science begins in the pre-scientific stage, and afterwards phases between normal scientific stage and revolutionary stage.

Is Cognitive Science a Science?

Before touching upon cognitive science's placement within Kuhn's stages of science, it is necessary to determine whether cognitive science actually is a science. The work of a scientist consists in putting forward and testing theories, that can be wrong, that can predict, and that can be applied to the real world. However, a defining and essential part of the scientific method is replicability, which I will define as the ability of an entire study to be reproduced. Another important aspect of science is that science is falsifiable. The philosopher of science Karl Popper emphasized the importance of the problem of demarcation and offered a clear criterion that distinguishes scientific theories from mythological claims (Popper, 2005). Popper introduced falsification: "statements or systems of statements, in order to be ranked as scientific, must be capable of conflicting with possible, or conceivable observations" (Popper, 1962, p. 39, as cited in Pigliucci & Boudry, 2013). The quote illustrates that for theories to be scientific, the predictions must be possible to be proven false. When theories are falsified, scientists must aim to produce new falsifiable predictions (Popper, 2005). As Popper distinguished between science and non-science, he stated non-science to consist of claims presented as being acceptable scientifically, but not justifiable by the scientific method (Popper, 2005).

In this case I will argue that cognitive science is using the scientific method, and therefore should be considered as a science. Furthermore, I will argue that computationalism previously has been the dominating paradigm within cognitive science. The interdisciplinary nature of cognitive science draws and includes knowledge from the previously mentioned fields, and with computationalism as the dominating paradigm within cognitive science, the scientific method emerges as the methodology within computationalism. The development of computationalism made it possible to create models, illustrate how representations are observable in the brain using EEG, and analyze statistical datasets to which a general tendency or prediction in society can be created. EEG provided a tool for researchers within computationalism, which made it possible to test their hypotheses using the scientific method. More recently, functional Magnetic Resonance Imaging (fMRI) has made it possible to detect activation in certain brain areas. The computationalist idea of having separate modules in the brain for separate functions, just like a computer, has gained more credence since the aforementioned techniques were developed. The development of computationalism and its methodology made it possible to come up with theories, which can be wrong, predicting and capable of being applied to the real world. This is the aforementioned well-known fundamental principle of science, and emphasizes the point of why cognitive science should be considered a science. Furthermore, when behaviorism attracted criticism during the cognitive revolution, computationalism became the new dominating paradigm. Where behaviorism only was concerned with external processes, computationalism focused on the internal processes, but kept the idea of the importance of scientific methods known in behaviorism and therefore involved computationalism's own previously mentioned scientific methods. To further argue that a paradigm shift occurred from behaviorism to computationalism, Friedenberg & Silverman (2006) states:

> Unlike the science that came before, which was focused on the world of external, observable phenomena, or "outer space," this new endeavor turns its full attention now to the discovery of our fascinating mental world, or "inner space." (Friedenberg & Silverman, 2006, p.2)

Friedenberg & Silverman (2006) emphasize that a shift has taken place; from the focus of external phenomena to the internal phenomena – to our mental world, our mind. Additionally, they argue that the focus of computationalism is the mind based on the idea of computation, which they define as information processing (Friedenberg & Silverman, 2006).

Cognitive science may appear as a speculative field to some because of its including elements that are implicitly philosophical, but this does not classify cognitive science as a non-science. Aspects from philosophy and psychology contribute to both internal and external knowledge of human behavior and mind, creating ideas for further research – research to be produced using the scientific method drawing from the aspects within computationalism. The different fields contribute greatly to the computationalist paradigm and its methodology within cognitive science, and therefore it should be emphasized that these few elements do not make cognitive science non-scientific.

Cognitive Science in Relation to Kuhn's Theory of Science

Now established that cognitive science is in fact a science, I will argue that cognitive science is in the beginning of the revolutionary stage. As previously argued, cognitive science once had a dominating paradigm, computationalism, and can therefore not be considered to be in the pre-science stage. In the pre-science stage, it is characteristic that an overall paradigm has not yet been found, however, it is clear that cognitive science shared an overarching world view in computationalism. The modules of human information processing systems such as attention, perception, and so forth have been the focus of research, as the clear majority of research has been carried out under the assumptions of the paradigm. Miller (1979) emphasizes this shared assumption, when talking about the creation of cognitive science. He left the symposium in which cognitive science was conceived with this remark:

> [W]ith a strong conviction, more intuitive than rational, that human experimental psychology, theoretical linguistics, and the computer simulation of cognitive processes were all pieces from a larger whole, and that the future would see a progressive elaboration and coordination of their shared concerns (Miller 1979, as cited in Bechtel, Abrahamsen, & Graham, 2001, p. 2154).

Miller expressed that he was with a strong conviction that the different fields would merge into one field to elaborate on the different field's shared concerns. This field became known as cognitive science.

Blurring of The Paradigm

However, cognitive science is starting to drift away from the stage of normal science and is therefore entering the beginning of revolutionary science. Multiple anomalies are starting to gather up, challenging the paradigm. Researchers start finding tendencies, which computationalism as the paradigm cannot answer. As Kuhn stated, the more anomalies that appear, the weaker the paradigm becomes. As an example, the problem of the replication crisis should be considered, where researchers start to make provisional solutions, which makes the results hard to replicate. In a recent study by the Open Science Collaboration (2015), researches attempted to replicate 43 published cognitive psychology studies. The study succeeded in replicating only 50 % of the original and statistically significant results from cognitive psychology, which shares the paradigm of computationalism (Collaboration, 2015). It was shown that scientists used questionable research practices such as p-value rounding to publish their papers with significant results. Thus, it can be argued that computationalism does not produce replicable studies half the time, which also could count against the statement that cognitive science is a science. This indicates that the current scientific method should be evaluated, as doubts of the scientific method within computationalism have been cast. Since the study illustrated that it is fairly easy to cheat with statistics, and thereby the results, a new scientific method or a reevaluation of the current method, is needed - and for that perhaps a new paradigm is needed. This viewpoint is further emphasized in the following quote:

> Nevertheless, 'negative' results may be very important for several reasons: they may provide more balance for a subject area thus far supported only (or primarily) by positive results. … They may indicate that a subject area is not as mature or clearly defined as previously. … They may show that a particular line of research is not worth further efforts …, or that our current methodologies are inadequate for producing a definitive result. (Browman, 1999, p. 301)

Browman (1999) explains that negative results, as those shown in the study of the Open Science Collaboration, might indicate that a subject, such as computationalism, is not clearly defined or that the current methodologies are insufficient for producing conclusive results. This tendency of only publishing positive results might lead results to be inconclusive, lead scientists to be stuck in an insufficient paradigm, and not being able to predict or implement any results in the environment. Problems like the replication crisis appear as anomalies within the dominating computationalism paradigm. Since we have a paradigm, in which a replication crisis is present, the paradigm might not function in the environment for much longer as more and more of the results are not useful. This might indicate that the paradigm is drifting towards a new paradigm using new methods. In this regard, Kuhn highlights a characteristic for a paradigm shift: "All crises begin with a blurring of the paradigm and a consequent loosening of the rules for normal research." (Kuhn, 1970, p. 84). This is exactly what the replication crisis leads to; a loosening of the rules for normal research.

A Weakened Paradigm

The computationalist paradigm was questioned by the philosopher John R. Searle who presented the Chinese Room Argument as a counterargument to Turing's test and computationalism as a whole. The Chinese Room is a thought experiment, where a non-Chinese speaker sits in an isolated room. Outside the room, Chinese speakers formulate a question to send into the non-Chinese speaker. The non-Chinese speaker uses a rule ledger to produce an output as an answer to their question. Searle (1980) argues that the Chinese Room is computationalism in action as it is identical to any computational model of cognition. According to Searle, a computationalist would claim that since it can be seen as a computational model, there must be understanding in the room, as the non-Chinese speaker must be doing computation. However, Searle argues that even though the non-Chinese speaker is indistinguishable from a native Chinese speaker, the non-Chinese speaker still does not understand Chinese, but is just manipulating symbols. In contrast to Turing, who accepts computationalism as the dominating paradigm and believes that minds are computing systems, Searle claims that programs are neither constitutive of nor sufficient for minds and thereby criticizes computationalism as a sufficient paradigm. The Chinese Room provides two main arguments against the computationalist view. Firstly, Searle states that brains, not computer programs, cause minds, as he emphasized no understanding was present in the room, only manipulation of symbols. Secondly, he concludes: "that actual human mental phenomena might be dependent on actual physical–chemical properties of actual human brains." (Searle, 1980, p. 423). Searle claims that brains must have something that causes a mind to exist, yet undiscovered by science, but which must be true, since minds exist. Furthermore, he states that a computer program cannot create a mind, since programs do not have this "something" that produces the mind. Thus, he concludes that brains do not use a computing system to produce a mind (Searle, 1980). These thoughts created anomalies and an uncertainty of computationalism functioning as a dominating paradigm, and the paradigm is weakened as a result.

The Mind as a Network

The common view of computationalism holds that cognition occurs at the level of symbols, claiming that symbols are arbitrary with respect to what they represent. Where computationalism describes cognition in terms of symbol manipulation and representation, another movement within cognitive science, known as connectionism, suggests that we can connect cognitive, computational, and physiological levels of analysis using artificial neural networks. Artificial neural networks can be understood as a computer simulation of how networks of neurons perform tasks. This idea means that connectionists claim the neurological structure of the brain to be fundamentally important (Coughlin, 2010). Connectionism has a long story, tracing its origin back to the 1940's, where ideas of how to implement logical functions with the help of networks of simple units were developed (Pfeifer, Schreter, Fogelman-Soulié, & Steels, 1989). However, the boom of connectionism originated approximately throughout the last 20 years, when the rapid development in artificial intelligence occurred (Havel, 2005).

There are a number of defining features which are common to all connectionist models. First, processing is expected to occur in a network of simple elements such as neurons. The second characteristic feature is that all knowledge is stored in the weights between the elements; the strength of connections between neural-like elements. Third, all units perform a simple combination of their inputs by multiplying or adding all inputs, and thereby learns by modifying these input and output weights (Schneider, 1987). The major difference between computationalism and connectionism is knowledge representation. Where computationalism, as earlier mentioned, use symbols to represent information, information in connectionism is represented as a pattern of activation in the network (Friedenberg & Silverman, 2006).

The development within artificial intelligence made it possible to run extremely large and time-demanding simulations on computers and to develop artificial neural networks. This development made it possible to model the human mind in several ways using complex and layered artificial neural networks. This availability of computer resources and the idea of neural networks made a number of researchers begin a movement toward modeling connectionist systems, which indeed have influenced and integrated into computationalism (Schneider, 1987). However, there are some limitations within connectionism. Most artificial neural networks are only capable of limited representation, meaning the representation do not sufficiently reflect the complexity of the human conceptual faculty (Friedenberg & Silverman, 2006). Despite the limitations, the connectionist models have contributed to the computationalist paradigm and simultaneously created doubts of computationalism as a sufficient dominating paradigm and questioned the scientific methods within. Researchers start to claim that in order to understand the human mind, cognition and behavior, it is necessary to investigate the interaction with the world and how environment interactions relate to experience, not just what comes in and out as a computing system (Rohde, 2010).

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Embodied Cognition – The New Portrait of Human Cognition

The new puzzle

Whilst computationalism is being criticized, embodied cognition arises as a possible new paradigm within cognitive science. Contrary to computationalism, embodied cognition is of the understanding that the mind can't be understood as a computing information processor which is independent of the sensory input and motor output to which it is connected. Instead, embodied cognition focus on the informational relations between cognitive operations and physical contact. These aspects are inseparably linked and together form the matrix within all aspects of mental life are embedded (Davis & Markman, 2012). This means that cognition cannot be explained by physical contact alone nor by cognitive operations alone; cognition happens in the interface where the organism and the environment meet.

Findings such as the existence of mirror neurons caused a greater emphasis on embodied cognition. In multiple brain-imaging studies, mirror neurons showed activity both when participants performed an action themselves and when participants observed an action made by others (Iacoboni et al., 1999; Kilner, Neal, Weiskopf, Friston, & Frith, 2009). These studies illustrate the connection between the organism's body, the internal processes and the interaction with the environment. This approach is a radical break from computationalism, where the body is emphasized as not necessary for cognition.

The significance of embodied action in the study of human mind has often not been recognized by scientists: In cases where the participant was to move to respond to stimuli in a fMRI scanner, like pushing a button, the scientists often eliminated the movement from the understanding of the processes involved in perception and cognition. However, several studies show that more scientists start paying more attention to embodied action when studying different cognitive phenomena (Bertenthal, Campos, & Kermoian, 1994; Institute & Toronto, 2000). Take mental imagery as an example: Since scientists started paying attention to embodied action, it has been suggested that various aspects of visual and motor imagery share a joint representational, and possibly neuropsychological, substrate (Jr, 2005). This new attention towards embodied cognition illustrates the importance of embodied cognition within human cognition and how the field might provide a different picture of human cognition than what traditionally has been assumed within cognitive science. As Sheets-Johnstone (1999) states, viewing the brain simply as an information-processing or as a computational device, as the center of cognition, ignores the centrality of animate form in human thought. The mind is based on ideas that are closely related to brain representations of the body and to the body's action in the environment. In relation, gestures seem to start gaining more attention in different studies (Hostetter & Alibali, 2008). Since humans use gestures to express knowledge, it can be argued that knowledge itself must be tied to the body. A clear connection between internal processes and external actions is seen when humans perform actions: when our bodies move forward, the retinal pattern we perceive expands outward, and when we move backwards, our retinal pattern contract inward (Hostetter & Alibali, 2008). This indicates that embodied cognition seems to help to the understanding of the relationship between internal processes and external action, as perception determines potential action, just as action determines what is perceived.

These ideas spread more anomalies to computationalism as the dominating paradigm, and at some point, a revolution is necessary. According to Kuhn, paradigms are incommensurable (Kuhn, 1970), which computationalism and embodied cognition in many instances are. Where computationalism states that the mind is a computing system, embodied cognition holds that the mind cannot be reduced solely to the brain, but is instead connected to both the body and the environment. We're starting to drift further into embodied cognition as the dominating paradigm.

Conclusion

Cognitive science developed due to the cognitive revolution, which brought the study of the human mind back into experimental psychology. The developments within computer science and artificial intelligence led to the conception of computationalism, and the field became the dominating paradigm within cognitive science, stating the mind is a computing system. Several anomalies within computationalism started gathering up, and a considerable doubt of whether computationalism is a sufficient paradigm has attracted more attention. This attention is especially due to the emergence of embodied cognition, where studies show the importance and the clear connection between internal processes and external actions. Embodied cognition provides a different picture of human cognition than what traditionally has been assumed within cognitive science, and this depiction and the findings within the field is exactly what will draw us into the middle of a Kuhnian revolution. Cognitive science will soon be present with the decision of which paradigm to reject and which way to go. We are in the beginning of a Kuhnian revolution.

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