The Contributions of Cognitive Science Essay

Arguments for the ability of Cognitive Science to make important, unique contributions to improving the methodological and theoretical foundations of psychology and related sciences

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Introduction

My grandfather, when asked what he wanted to do with his life, chose to describe his goals in one sentence: “My aim is to be a useful human being”. At the personal level, this seemingly simple philosophy of life has made me think about my choices and the impact these choices may have upon the world. As a newly enrolled university student, I have chosen to embark upon a career in science, specifically a career in Cognitive Science. Following the above-mentioned “philosophy of life”, I need to ask myself, what contributions can Cognitive Science make to our understanding of the world, in particular human psychology?

In the essay, I will discuss the potential contributions of Cognitive Science. In particular, I will discuss the challenges associated with the current so-called “replication crisis” in modern psychology – following the 2015 Reproducibility Project, published by the Open Science Collaboration. To explore the possible contributions of Cognitive Science, I will, first, need to discuss what constitutes scientific knowledge and progress. I have chosen to focus on the concepts of inductivism, Popper’s ideas of falsificationism, and Kuhnian paradigms. According to these concepts from philosophies of science, how is scientific knowledge produced, how do we evaluate and test theories, and how does science develop and change over time? Furthermore, based on the contributions of these approaches, how can we determine what constitutes good scientific practice. In addition, I will discuss the field of psychology that Cognitive Science springs from, with particular focus on Cognitive Science. I will attempt to argue whether scientific studies published by cognitive scientists are conducted in accordance with the requirements set up by the philosophies of science that have been covered and argue how the apparent “replication crisis” could be part of a natural, and productive, process in the development of the scientific field, rather than a fundamental crisis in the fields of psychology and Cognitive Science.

Theories of science

As many a newly enrolled student, at the beginning of studies, I held the belief that science, more or less represented finite truths. A university study gradually exposes the student to the notion that science, perhaps somewhat sadly, stems from and is conducted by mere mortal researchers that are set in a world containing an infinite amount of conditions and outcomes to any experimental testing.. An introduction to science opens one’s eyes to and stimulates the need to be highly critical towards the published scientific results and the conclusions drawn on the basis of those findings. While science may often be defined by the layman as a “search for truth”, Alan Chalmers, in “What is this thing we call Science?" (1999), argues that science may in fact not be a search for a definite truth and emphasizes how the confrontation between different views determine the strength of theories (Chalmers, 1999). First, he discusses the idea that scientific knowledge might be derived from facts, in the form of logical reasoning, also called deduction. Chalmers defines logic, or deduction, as being "*concerned with the deduction of statements from other, given, statements.*" In a logically valid deduction, this means that if a given statement, or premise, is true, then a statement logically deduced from this premise must also be true. However tempting this simple definition may be, in general, scientific knowledge cannot be logically deduced, the reason being that scientific knowledge, produced by researchers, can ultimately only be derived from empirical data, extracted from a particular observation or experiment, at a particular point in time, and during a particular set of conditions. Such data can only produce observational statements. Chalmers provides an example of deductive reasoning based on an observational statement: "*Metal* x^n *expanded when heated on occasion* t^n" and proposes the conclusion that all metals expand when heated. As Chalmers explains, this argument is not logically valid as there is no logical guarantee that one cannot come across a sample of metal which might not expand when heated. In general, researchers can only produce data from a finite amount of situations. Logically, this ultimately means that researchers can never validly deduct that a scientific statement based on the data they are able to produce is true.

In attempts to deal with this problem of logical deduction, competing views have evolved. Some researchers have turned towards *inductivism*. Inductive reasoning, in contrast to deductive reasoning, establishes general conclusions based on a finite number of facts. Chalmers explains the principles of induction and a good inductive argument with the following sentence: "*If a large number of A's have been observed under a wide variety of conditions, and if all those A's without exception possess the property B, then all A's have the property B.*" However, inductive reasoning also runs into several problems. For example, how large is a sufficiently large number of observations and what constitutes the variety of conditions that needs to be tested? Furthermore, Chalmers mentions David Hume, who has posed the problem of how to justify induction. It cannot be justified by logic, as it would be impossible to form a valid deduction. In addition, it cannot be justified by producing premises in the form of all the successful uses of induction, as this would be an inductive argument in itself. Modern inductivists attempt to deal with these problems by, instead, referring to a *probable* truth. Again, we run into the problem with the finite number of observational statements we can produce and the infinite number of situations a theory produces. Based on standard probability theory, we thus end up with zero probability for any scientific theory or law. Chalmers introduces the Bayesians, a group of modern inductivists, who have tried to solve this problem. One of the ideas that they introduce, is the notion of subjective prior probability based on the individual researcher. Induction is not without problems, when combined with deduction, it lays the foundation for how scientific knowledge is produced. Induction and observational statements are used to produce laws and theories that can be deducted into predictions and explanations, as seen in the model from Chalmers book (figure 1, appendix).

Falsificationism, initiated by the Austrian-British philosopher Karl Popper, challenges the classical true inductivists by proposing that while we are ultimately never able to truly confirm a theory, we can in fact disconfirm the theory (Popper, 1935). According to falsificationism, theories are strengthened by how they can be logically deducted to be wrong. Therefore, falsificationism denies the need for induction. Popper, looking at the Freudian and Marxist theories of his time, believed such theories to be to be way too flexible. Any possible observation could be accommodated in and explained by the theories, and they thus explained nothing at all. An easily grasped example is the theory of God. Any natural disaster or miracle can be explained by the wrath or benevolence of a higher being and can therefore not be disproven. In contrast, a simple example of a falsifiable theory: "It never rains in Aarhus". This theory can be easily falsified by any single observation of rain in Aarhus and is therefore easily disproven. One consequence of this is that good scientific theories need to be very clearly stated, as vaguely presented theories can easily interpret observations and tests to be consistent with the theory. Induction constrains itself by only admitting theories to science that can be either proven to be true or probable. Chalmer explains how an inductivist might think about the admission of theories in science: "*We should proceed beyond the immediate results of experience only so far as legitimate inductions will take us*". Falsificationists, in contrast, encourage the bold and speculative theories, as long as they are falsifiable. Falsificationists abandon any claims that theories can be true or probable, insisting that we can never gain the exact truth, given that there is an infinite number of hypotheses or conditions associated with any knowledge of the universe we try to gain. This means that the core goal of science, in the view of a falsificationist, is to falsify theories and then gradually replace the falsified theories with improved falsifiable theories. It should be noted, however, that falsification is not without its own problems. Most prominent, it may be nearly impossible to discern whether a theory is actually falsified. When a theory is falsified by a certain observation that clashes with the theory, we often cannot be sure whether the theory is wrong or the observation is erroneous. We cannot, at the time of an experiment, be certain that the instruments or methods used are adequate, and therefore we are unable to falsify any theory with certainty.

What can be seen from both falsification and inductivism is that progress in scientific knowledge is viewed as stemming from the accumulation of observations and therefore builds on and is dependent on prior knowledge. Thomas Kuhn (Kuhn, 1970) did not believe that it was sufficient to explain the development of science as a simple linear historical progression. While we may compare the achievements of Galileo to modern science, it makes perhaps more sense to compare Galileos thinking to that of his peers and rivals at the time. From these ideas, Kuhn built his framework-based theory of scientific revolutions. Kuhn draws certain parallels between major scientific achievements of, among others, Aristotle's *Physica* and Newton's *Principia*. First, both theories were particularly able to attract a large group of followers, and secondly, they both left a sufficient number of unsolved questions for these followers to try to answer. Kuhn referred to these scientific achievements as "paradigms". In his description of scientific paradigm, Kuhn states: "*I mean to suggest that some accepted examples of actual scientific practice-examples which include law, theory, application, and instrumentation together provide models from which spring particular coherent traditions of scientific research*." (Kuhn, The Structure of Scientific Revolutions, Second Edition Enlarged, p. 10, 1970). Kuhn goes on to state that what characterizes a mature science, is the acquisition of a paradigm. This is the stage where scientific fields are most productive and the largest body of knowledge would be developed. Kuhn refers to this as "normal science" as opposed to a "pre-science". At some point, too many questions and problems that cannot be solved occur in a field. This marks the beginning of a scientific revolution and a time of paradigmatic crisis. As a possible consequence of the crisis and the attempts to answer the problems that cannot be solved within the old paradigm, this may lead to a new large scientific achievement which develops into a new paradigm with a large number of followers and we thus return to a new normal science. In this way, a science matures and develops in a constantly evolving process, not in a linear fashion, but in the stages: normal science, unsolved questions, crisis, new paradigms, and new normal science.

Understanding Cognitive Science within the framework of theories of science

The general outline of theories of science described above provides us with a framework to potentially understand the development of the particular field of Cognitive Science, its potential as a productive and useful science, and some of the current challenges. The concept and study of cognition springs from the field of cognitive psychology, emerging in the 1960s and 1970s in attempts to counter the – at the time – dominant radical behaviorist psychology represented by B.F. Skinner (Skinner, 1974). Radical behaviorism restricted its area of study, theories, and hypotheses exclusively to observable behavior and claimed psychological theories of internal mental processes, for example emotions and cognitions, to be "mentalistic" and unscientific. With the development of new research methods, other researchers started to place renewed emphasize on the internal mental operations (Friedenberg & Silverman, 2012), attempting to understand and describe the mind using the recently developed computers as a model. The central theoretical perspective on the mind in Cognitive Science has thus mainly been of the mind as an information processor and the idea of computation, springing from developments by, among others, Turing in the 1940's. Generally, there is consensus that while the foundations of Cognitive Science were formed during a symposium at MIT in 1956, it was first in 1976 that a specific scientific society and journal was created with the name (Bechtel, 2001). In "Cognitive Science: An Introduction to the Study of the Mind" by Jay Friedenberg and Gordon Silverman, Cognitive Science is roughly summed up to be the interdisciplinary study of the mind using scientific method. Paul Thagard, in 2009, refines the interdisciplinary nature of Cognitive Science (see figure 2, appendix). He includes psychology, philosophy, linguistics, anthropology, neuroscience, and artificial intelligence along with the strength of the interdisciplinary ties between the different disciplines. Moreover, recently additional disciplines, such as sociology, evolutionary ecology, appear to be included in Cognitive Science (Serrano, 2009).

The Cognitive Science Society publishes two journals; TopiCS and Cognitive Science. The Cognitive Science Journal editorial board has chosen ten classical articles. These articles were chosen based on their impact, innovative qualities, and importance in furthering theoretical development in the field of Cognitive Science. These articles can thus be seen as a core body of knowledge produced in Cognitive Science. In one of the articles, authored by Philip Johnson-Laird, the focus is on mental models in Cognitive Science. If Cognitive Science can be seen as contributing to the theoretical and methodological foundations of psychological science, then a respected core article in the field, such as this one, should be able to be understood within the framework proposed in the theories of science described above. In the article, Mental Models in Cognitive Science, Johnson-Laird discusses the ideas of syllogistic inference, the drawing of conclusions from two premises (Ex All A's are B's and all B's are C's, concluding that all A's are C's), originally theorized by Aristotle. Johnson-Laird proposes his own hypothesis that we manipulate mental models in tasks that require syllogistic inference. This means that in such a task people will conduct a "thought experiment" where you construct a mental model (a room) of relevant individuals (could be A's, B's or C's) and form identities between them in a spatial manner (for a more respectful explanation see Johnson-Laird, Mental Models in Cognitive Science, p. 79-81). Before explaining his theory, he poses four criteria for evaluating theories of syllogistic inference. By introducing these criteria, he provides premises for how a theory, including his own, can be tested and falsified. Like Einstein posed a falsifiable prediction for his theory of the gravitational deflection of light, an example put forth by Popper himself, Johnson-laird includes criteria that his theory has to be able to predict or include to be valid. As he puts his theory of mental models to the test, Johnson-Laird explains: "*Likewise, the theory obviously predicts that those premises for which the heuristic yields a valid conclusion should be easier to cope with than those premises for which a valid conclusion emerges only after submitting the model* (mental model) *to a logical test. This prediction was readily confirmed: 80.4% of responses to the first sort of premises were correct whereas only 46.5% of responses to the second sort of premises were correct, and this pattern of results was obtained from each of the subjects who was tested.*" (Johnson-Laird, p. 81-82, 1980) The experiment mentioned in the quote was conducted by Johnson-Laird and Steedman in 1978, two years before the publishing of this article. This suggests that Johnson-Laird used the inductivist method, proposed in figure 1 (appendix). Furthermore, the experiment tests a prediction based one his theory that could have been falsified. Another example of his use of falsification and induction is present earlier in the article. Here Johnson-Laird introduces another hypothesis; the atmosphere effect. This hypothesis proposes that a certain "atmosphere" created by premises in a logical deduction, predisposes a participant to formulate certain conclusions as opposed to others.

1. Whenever at least one premise is negative, the most frequently accepted conclusion will be negative; otherwise, it will be affirmative.
2. Whenever at least one premise is particular (i.e. it contains the quantifier "some"), the most frequently accepted conclusion will be particular; otherwise it will be universal (i.e. contain either "all" or "none").

The atmosphere hypothesis as formulated by Beggs & Denny 1969 (Johnson-Laird, 1980)

Johnson-Laird goes on to pose an example that was used in and experiment he conducted two years earlier. He had participants finding valid conclusions for the premises: "Some of the beekeepers are artists." And "None of the chemists are beekeepers." 12 out of 20 participants claimed that there were no valid conclusions but Johnson-Laird points out that the conclusion “Some of the artists are not chemists” is valid and moreover, it is congruent with the atmosphere hypothesis: “*Particular because the first premise is particular, and negative because the second premise is negative.*” Therefore, this falsifies the atmosphere hypothesis. By this method, Johnson-Laird follows the ideas of Popper in falsification. He pulls out a theory that has been posed on the subject he is trying to investigate and tests a prediction that is drawn from it, to prove it wrong. At the same time Johnson-Laird also acknowledges the problems that arise with falsification. Because theories are extremely hard to falsify definitely, instead of completely denying the hypothesis, he goes on to argue that the hypothesis at least requires modifications.

In the article by Johnson-Laird, we see proofs of the scientific frameworks proposed by inductivism and falsification, but we have yet to answer whether Cognitive Science is a mature and developing science in accordance with the ideas of scientific revolution by Kuhn. In his article, Johnson-Laird discusses how his theory eliminates the need for at specific set of rules of inference: “*A computer program that I have devised works according to the theory and uses no rules of inference. Its power resides in the procedures for constructing and manipulating models - a power which in turn demands at the very least the recursive power of list-processing operations.*” (Johnson-Laird, p. 84, 1980). We see here that he uses computation to simulate how his theory might work in the brain and he does this throughout the article, illustrating how psychology had undergone a paradigm shift from behaviorism towards computationalism. This new paradigm was to become the central inspiration for Cognitive Science (Bechtel, 2001). The ideas of British mathematician George Boole in his book “The Laws of Thought” on formal logic produced the idea of cognition being implementation independent, systematically interpretable symbol manipulation. A central component of computationalism was the modularity of the internal processes of cognition. It allowed researchers in Cognitive Science to delve into specific areas of cognition like attention, memory or vision and develop computational models that could be tested through simulation or logic. In the framework of this new paradigm, several laws, hypotheses and theories have been developed. Examples are Baddeley’s model of working memory and Marr’s Tri-Level hypothesis. More recently, however, the idea of cognition as computation has been challenged. John R. Searle, for example, in 1980 published an article titled “Minds, Brains, and Programs”. “*I have no objection to the claims of weak AI, at least as far as this article is concerned. My discussion here will be directed at the claims I have defined as those of strong AI, specifically the claim that the appropriately programmed computer literally has cognitive states and that the programs thereby* *explain human cognition.*" In this article, Searle questions the computation model proposed by Schank and Abelson (1997), using the Chinese Room Argument. The argument involves a man who does not speak Chinese who is locked in a room and given a three batches of Chinese writing; script, story and questions. The man is given a set of rules, a program, for correlating symbols of one batch of symbols to another. The symbols that the man sends out of the room using the program are called answers. A one point, the man might become so adept at correlating the symbols that even though he does not understand one word of Chinese, the answers are indistinguishable from the answers that a native Chinese speaker produces. Searle uses this story to argue that although a computer might be able to mimic human behavior in terms of passing the Turing test, computations will not be able to represent a real understanding of what it is processing. This argument has provided a serious challenge for the computationalism paradigm. If there is no true understanding in the Chinese room, which manipulates formal symbols, then computational programs can never explain the human mind. This has led some researchers to consider the theory of the mind as an information processor more carefully and new ideas, for example connectionism, neural networks and embodiment, are now pursued.

It would seem that, in Kuhnian terms, one of the central characteristics of the paradigm is being questioned and that the development of Cognitive Science stands at a crisis. Just as central aspects of radical behaviorism increasingly began to be challenged and failed to answer new questions posed in psychology, the paradigm of computationalism appears to experience the same kind of scientific tension. These developments suggest that, following the ideas of Kuhn, Cognitive Science is a mature science. One may conclude that, if a new paradigm within the field develops, which will be able to solve the contradictions, Cognitive Science will continue to develop and thus be able to contribute to the methodology and theoretical foundation in the investigation of the mind.

Replication crisis

The Open Science Collaboration project, 2015, published the article "Estimating the reproducibility of psychological science". The project tried to replicate 100 different studies in psychology and only found significant results in 36 percent of the replications. The question is whether the replication crisis represents a crisis of the central paradigm of psychology and, therefore, might influence the contribution of Cognitive Science, or rather a more general methodological problem. Furthermore, is the replication crisis unique for psychology?

In an article from 2005, the research methodologist John Ioannidis states that "*most research findings are false*". His main point is that the claims in current science, whether it is psychological or other, are too strongly based on results of single studies. Ioannidis points out that "*the high rate of non-replication (lack of confirmation) of research discoveries is a consequence of the convenient, yet ill-founded strategy of claiming conclusive research findings solely on the basis of a single study assessed by formal statistical significance, typically for a p-value less than 0.05*" (Ioannidis, 2005). Based on an extensive reviews of scientific publications and a statistical, simulation model, he concludes that whether a scientific claim is true depends on several factors, for example: the number of studies investigating the question, the statistical power of the study, the flexibility of the study design, and the magnitude of the effect found in the studies, together with other factors such as financial interests, researcher bias and editor bias in favor of certain theories and hypotheses – a view that is very similar to that of the subjective Bayesians in which the prior probability of a scientific claim being true relies on the researcher himself. The main argument here is that the replication "crisis" is not primarily a crisis of theories, but a crisis of statistical methods and publication practices leading researchers to rely too heavily on single, statistically significant results – a problem that may stem from pressures to publish in search of grants and funding, proposed by Yaffe, 2016. Furthermore, this problem is not a problem specifically related to one discipline, for example psychology, but a general scientific problem. The attempts of The Open Science Collaboration to conduct replications of a number of single, core studies in psychology is, in fact, a welcome attempt to address this problem, if only by producing controversy and debate, as seen in comments and responses on the article (Gilbert, King, Pettigrew & Wilson, 2016). Even though the project showed a very low replication rate this does not conclude that we are in a scientific crisis. Instead, I would suggest that it is an indicator of Psychology and Cognitive Science being mature sciences that addresses some more general methodological problems, for example relying too much on statistical significance, and scientific publication issues and guide us to be more critical towards study designs, place renewed focus on replication and to be more cautious when we interpret results of a single or few studies – especially when it is based on significance only. This is further strengthened by the fact that we, the new generation of cognitive scientists, are made to reflect on this issue.

Conclusions

To sum up, by using the frameworks provided by some of the prominent philosophers of science, it can be argued that Cognitive Science, as a particular field within the science of the mind, is a mature science. Furthermore, Cognitive Science is a progressing science, set midst a scientific revolution, and the so-called replication crisis is not necessarily a crisis of psychology or Cognitive Science, but a more general issue that applies to all sciences. Furthermore, this is not a crisis that is being ignored, but addressed in the scientific community and in the education of the students. Thus, we the students of this tradition are left with many possibilities for developing new methods and testing new hypotheses within an expanding theoretical framework of the mind, while being critical towards other and our own scientific method. One of the particular strengths of Cognitive Science lies in its interdisciplinary nature. Friedenberg and Silverman (2012) illustrate this strength with the classical metaphor of the four blind men who approach an elephant from different sides. The first touches the tusks and imagines a giant carrot, another touches the ears and believe them to be big fans. The third touches the leg and imagines a tree trunk and the fourth touches the tail and believe it to be a rope. Individually, the four men are unable to realize what is in front of them, but if they share their findings, they may easily have grasped that it is an elephant. In this way Cognitive Science may be able to increase our knowledge of the mind in a way that no single discipline can. However, J. Ignacio Serrano, in his article “Cognitive? Science?” from 2013, criticizes the actual unity in Cognitive Science. He believes that there is a lack of true interdisciplinarity, mainly due to the lack of a more precise definition of cognition. I believe this lack of a precise definition and actual interdisciplinarity only further supports the point that Cognitive Science is in a position to further develop paradigmatically, leading to new research questions and new approaches that better are able to explain these questions. Again, we see that the community of Cognitive Science are critical towards how the research is conducted which will lead to significant contributions the scientific study of the mind and psychology in the future. In following Cognitive Science and committing myself to its area of study and scientific practice, I believe, I will be able to be a useful human being.

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Appendix

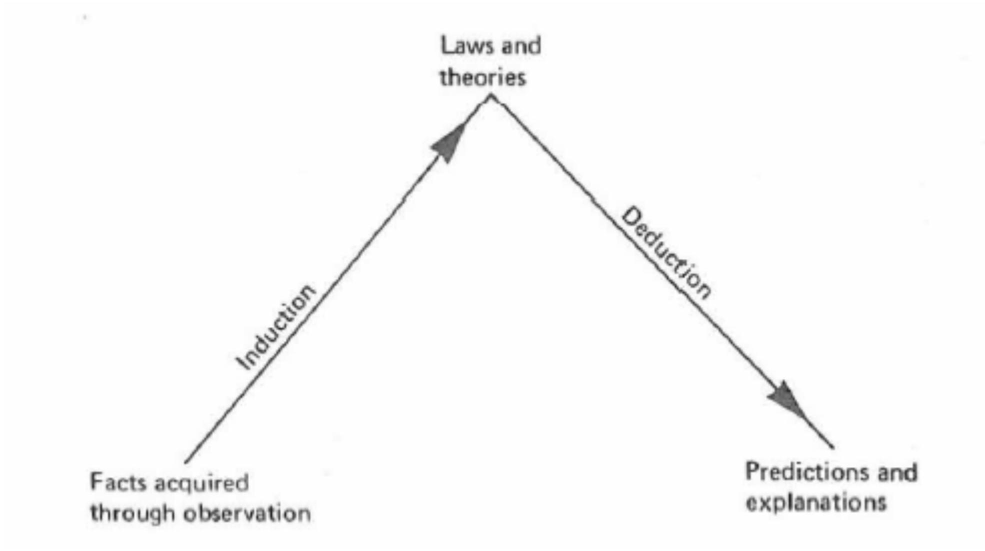

Fig. 1. The laws and theories that make up scientific knowledge are derived by induction from a factual basis supplied by observation and experiment. Once such general knowledge is available, it can be drawn on to make predictions and offer explanations (Chalmers, 1999).

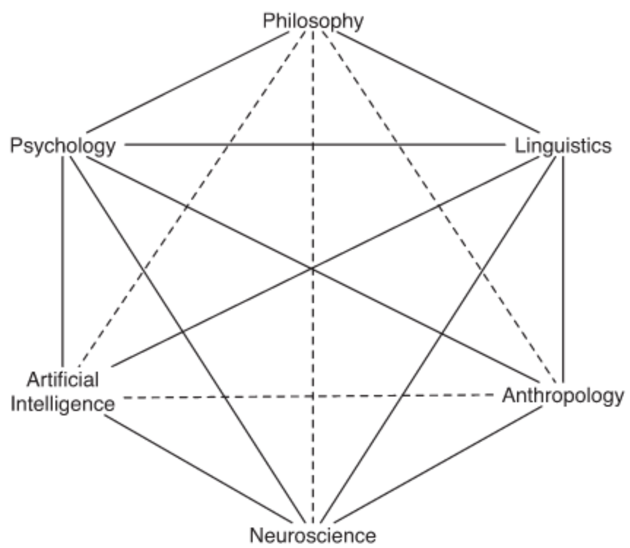

Fig. 2. Connections among the Cognitive Sciences, based on Gardner, 1985, p. 37, from a 1978 Sloan Foundation report. Unbroken line indicate strong ties and broken lines indicate weak ties. (Thagard, 2009)