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Cognitive science in respect to Kuhn's theory of science and its stages

In any scientific field, it is of high importance to acknowledge the current position of the specific scientific approach, in order to know where it is heading. For the field of cognitive science, the task of demarcating its current position and overarching paradigm is a challenge. An implication of being a widely interdisciplinary field causes constant motion as several different fields try to shed a light on the workings and underlying processes of the mind. Although, it has been possible for cognitive scientists to agree on the thought that the mind is the software of the brain. In the course of this essay I will question the paradigm of cognitive science, and in the process argue for the position of cognitive science in respect to Thomas Kuhn's theory of scientific paradigms. It will be argued that of the three stages of Kuhn's theory, Cognitive science is situated in a scientific revolution. To be exact I will argue that cognitive science is experiencing a *drift* since there is evidence hinting that the paradigm which have been dominating the field in the recent years, is shifting towards something new, yet undetermined. To argue the above stated, the arguments presented in this essay will be based on Kuhn's criteria for each of the three stages, pointing out why the field of cognitive science fit into one, and thus not the other two.

The first argument will be arguing why cognitive science is not in the pre-science stage, focusing on what the criteria underlying for the stage, and why they are not met by cognitive science. As there are three overall phases of science in the theory of Kuhn, the arguments for the next stage, pointing out why cognitive science have met the criteria of being a paradigmatic or normal science, follows nicely. In order to argue for a scientific revolution in the field of cognitive science, it has to be stated how the field got there. No scientific field can claim to be in a revolution, before having stated their overarching assumptions and worldview, and consequently stated itself as a normal science. Here the scientific validity of cognitive science will be discussed and evidence of a dominant paradigm of the field will be presented. The remaining arguments concerns why the paradigm is drifting, and hence argue *why cognitive science is in the stage of revolutionary science.* Presenting evidence pointing to a new paradigmatic era for the field of cognitive science will make it clear by the end of the essay *why* the field is situated where it is argued. To finish off, I will give my suggestion to which direction the field is headed.

In order to present my arguments to the fullest, I aim to define various yet critical terms to the subject and contention of this essay. These definitions will present themselves in the following paragraphs.

Kuhn, paradigms, and stages of science

Thomas Kuhn (1970) proposed a theory concerning three stages of science. It is a simple progress cycle, symbolising the stages which science passes through, through time, rather than progressing in a linear manner, which was the common conception before his theory. Instead of science being a steady accumulation of new ideas, every scientific field had to fit certain criteria in order to call itself a science. Kuhn developed his ideas following Karl Popper's thoughts on the demarcation problem, which is the known philosophical problem of marking which fields actually can be classified as a science, and which cannot (Hansson, 2017). Allchin (1999) interpreted on Poppers demarcation criteria and commented that his claims lay down some rough consequences described, as a 'deathblow' to a scientific theory, in the case of a sole anomaly detected in researching the specific theory. Kuhn proposes a contrasting and more loose approach to 'negative' results, as Allchin notes of Kuhn himself, they merely indicate "an incomplete recipe, nothing about the impossibility of 'positive' results" (p. 330). Kuhn differentiates between science and what he calls 'pre-science'. Once a field has met the criteria of being a normal science, it won't escape its scientific identity, and will endlessly be in the cycle of first being classified as normal science, then experiencing a model drift, a crisis, a shift towards a new paradigm, until once again returning to the stage of normal science.

Before further exposition of Kuhn's theory and the scientific stages, the term *paradigm* needs to be defined, as it is both of high vitality to Kuhn's theory as well as to the remains of this essay. A paradigm is in relation to this essay, defined as a certain model of comprehension, covering a number of grounding thoughts and assumptions about the field and its relation to the world, and hence provides the field to which it belongs, with viewpoints and a 'guidebook' on how to look at the emerging problems of the field, and thus providing a framework through which these problems can be solved. Kuhn described it as following "To be accepted as a paradigm, a theory must seem better than its competitors, but it need not, and in fact never does, explain all the facts with which it can be confronted" (Kuhn, 1970, pp. 17-18), hence saying that in order to be accepted, the framework merely has to be accepted as the best one present, not necessarily that the accepted paradigm in any normal science present a certain goal-stage of the field.

In the stage of *pre-science*, there is no dominant paradigm, and thus according to Kuhn, a field in this stage, cannot be declared a science. This stage is where all new sciences begin, and where there is an accumulation of effects while observing the world and collecting data. Once the field has developed a theory which can account for the majority of the gathered evidence, and which gains the support and acceptance from the field, then the field can pass onto the next stage of Kuhn's theory, and thus mark itself a *normal science.*

In the stage of normal science, there is an overarching paradigm in which the majority of the scientists have their basis, while attempting to solve the problems emerging in the field. A problem arises when observations made, start falling outside the paradigm and the model starts to drift. Kuhn (1970) criticises scientists of normal sciences ability, or lack of ability, to acknowledge when their model starts do drift. The attempt to hold onto the dominating paradigm becomes a tenacious affair, since what follows the drift of the model, is the traumatic crisis of the paradigm, where too many of the observations made do not fit into the paradigm:

> Normal science, the activity in which most scientists inevitably spend almost all their time, is predicated on the assumption that the scientific community knows what the world is like. Much of the success of the enterprise derives from the community's willingness to defend that assumption, if necessary at considerable cost. Normal science, for example, often suppresses fundamental novelties because they are necessarily subversive of its basic commitments. (Kuhn, 1970, p. 5)

Any dominant paradigm of any field will only last until it suffers its own crisis. As a paradigm drifts toward a crisis, the next stage of Kuhn's theory is reached, which is *revolutionary science*. After the occurrence of a crisis, the field will with time rise with a new theory which will gain acceptance and support because of its ability to contain observations better than the former paradigm. This theory will then be the new dominating paradigm as the field returns to the stage of normal science.

Cognitive science and historical context

Cognitive science can be defined shortly as the interdisciplinary study of the mind (Friedenberg & Silverman, 2006). A major hallmark of the field is its interdisciplinary approach, through which the scientific method is the one most applied, while other methods might also come into play, merely to a lesser degree. Researchers joined in the field are from a wide variety of more or less scientific fields such as psychology, philosophy, linguistics, artificial intelligence, neuroscience and more. Each aspect of the field provides a unique set of tools and perspectives, whilst working in concert through communication and cooperation across and within fields, all aspects of cognitive science aim to understand the same thing, namely *the workings of the mind.* Friedenberg and Silverman (2006) closes in on the mind by explaining the theoretical perspective, which is the framework that cognitive science has been based on, throughout the recent years. This framework is the grounded in the thought of computation, or information processing, and is called *computationalism.*

Computationalism has been the dominant paradigm for some time, as cognitive scientists viewed the mind as an information processor with both abilities to transform and represent information. A common analogy of computationalism which is of high abstraction level is the idea that like a software runs a personal computer, the mind is the software of the brain. Information received through perception is in this model equal to 'input', this input is stored in our memory and processed in the form of thought, which then serve as a basis for the 'output' such as language and behaviour (Friedenberg & Silverman, 2006, p. 3). Thus, intelligent behaviour can be "causally explained by computations performed by the agent's cognitive system (or brain)." (Piccinini, 2009, p. 515).

Accessing cognition through a view of computationalism has yielded many computational models, aiming to explore the essence of cognition and mental operations through a detailed process-based understanding of cognitive functionalities such as attention, sensation, perception, memory, and etc. These descriptions of cognition are embodied in computer programs and algorithms, based on computer science. Testing these models and adjusting them throughout the process, gives insight and explanatory value, as to what process underlies the task or mental operation, as an aims of computational models are to simulate or predict behaviour in the given or tasks similar to the one modelled. Computationalism aim to explain the underlying process of behaviour, down to the very detail. This way of thought is quite contrary the movement behaviourism, which dominated the field of psychology in most of the nineteen hundred, and in which B. F. Skinner, who was a proponent of the viewpoint, claimed 'internal processes' irrelevant for analysing behaviour (Cahn, Kitcher, Sher, & Markie, 1995), and thus only observable facts as a result of behaviour, were derived in the scientific inquiry of behaviourism.

The urge to state objective scientific value in the field of psychology emerged with the behaviouristic view. As a contrary to the thought of relying on introspection, which psychology in large did before behaviourism, the founding fathers of the movement, Thorndike, and Watson (Coplan, 2010), began investigating publicly observable behaviour, which could rely on the scientific laws of behaviour. The behaviouristic view was counter-revolutionized by the cognitive revolution, which was inevitably followed by the emergence of cognitive science (Miller, 2003), where the foundation in the thought of computationalism followed from especially Turing computation (Rescorla, 2017), as well as a vast technological progression.

Cognitive science is *not* a prescience – there has been an established paradigm.

For Kuhn (1970), the criteria of being a pre-science is to not have an overarching paradigm, since committing to one, is a prerequisite of normal science (Bird, 2013). As emphasised earlier, what cognitive science is closing in on explaining, is the mind, and the field is doing so primarily through the framework of computationalism (Friedenberg & Silverman, 2006). By claiming an overarching paradigm, the field limits itself from ever being classified as a prescience.

Although, there are different opinions in the field, discussing whether cognitive science qualifies as a science at all, on an equivalent level as other established sciences. Arguments against cognitive science and its establishment as a science contain among others arguments claiming a lack of boundaries in defining central objects and terms of study, i.e. cognition, and furthermore that the field is lacking a rigid and consistent scientific methodology and that the interdisciplinary nature of the field, compromises the field in claiming scientific identity and prestige as well (Serrano, Castillo, & Carretero, 2014).

For the sake of the contention of the essay, as well as to state my subjective belief, it is certainly argued that cognitive science *is* in fact, a scientific field. The arguments claiming cognitive science invalid in their scientific inquiry, is lacking acknowledgement of the interdisciplinary nature, because interpreting this hallmark as negative with respect to claiming scientific identity, is inaccurate. The interdisciplinary nature establishes a broad base of information. The field of psychology before the cognitive approach had no overarching theory or framework, only as the focus on cognition and the endorsement of the Silverman ref. information processing perspective became more prevalent, a more unified approach to the field came(Friedenberg & Silverman, 2006), which separated itself from behaviourism and the former establishment of psychology. Cognitive science doesn't claim its constitutes interdisciplinary parts as scientific in individual, i.e. psychology isn't known as a scientific field, but the manner in which parts of the psychological field *interplays* with the field of cognitive science, in concert with the remaining fields and the application of the scientific method, *makes* the field a scientific enterprise. A practice like cognitive science, which produces reliable theories as well as builds and affirms others, is a science.

Why cognitive science has met the criteria of being a normal science and thus has established itself as a scientific field

As identified by Kuhn (1970), the early stages of any science, is a period of time in which different researchers are "confronting the same range of phenomena, but not usually all the same particular phenomena, describe and interpret them in different ways" (Kuhn, 1970, p. 17). If one is to advocate for cognitive science in the prescience stage, the argument derived from this quote would on anew, be advocating the constraints of the fields interdisciplinary nature. To disprove this argument, and instead turn the argument into the contention advocated in this essay, it has previously been stated a number of times, that the view of computationalism provides a framework for cognitive scientists to work within. Thus, investigating the mind through computation provides a main phenomenon to be investigated, and thus serves as the paradigm at hand. The overarching paradigm is primary because it is the best framework yet, at explaining the findings, focus as well as contain the basic assumptions of the field at current place in time – hence not insinuating that there isn't a better paradigm to come. In line with this argument, it is once again relevant to draw on the first citation of Kuhn in this essay, situated on page 6, where it is mentioned that the overarching paradigm doesn't necessarily have to, and rarely if ever, explain all observations and facts with which it can be confronted (Kuhn, 1970). As the paradigm covers cognitive science and the respective parts of inquiry better than others hitherto, it is accepted, thus there will be fields or facts which the framework of computationalism will cover to a lesser extent.

Evidence of computationalism grounded in cognitive science are quite accessible when taking a glance upon the computational models emerged through the study. One which the experimenter himself, George A. Miller, claims to have taken place at the year of the conception of cognitive science (Miller, 2003), which is his experiment investigating the limits of cognition through testing the capacity of processing information in working memory. Miller observed that the approximate number of items (objects, numbers, etc.) one can hold in memory and repeat back in correct order is 7 ± 2 (1956). Another model of cognitive science investigating the ability of attention in relation to audition, is the attenuation model by Treisman(1964), in which she extends upon existing models of attention and related to mechanisms of perception, and as she noted herself, the model has been "defined in the language of channels, information, filtering processes and storage" (Treisman, 1964, p. 15), lingo very alike to the one applied, when dealing with computer processes. Models of attention as well other models have often applied a specific terminology concerning processes happening in either *serial* or in *parallel*. Processing in serial means that each representation is processed in separately. In a behavioural experiment, a serial process will express itself in terms of reaction time correlating with information load – an increased amount of information presented would thus result in an increased latency as the participant processes the information displayed. While a parallel process happens when an agent is capable of processing representations simultaneously, and thus reaction time would be independent of amount of information to process (Gazzaniga, Ivry, & Mangun, 2013). Saul Sternberg realized through his experiment in 1975 the distinction between the two types of processes, in his attempt to understand the mental architecture behind the task modelled concerning recognition memory (Gazzaniga et al., 2013). Connecting the theory of serial and parallel processes to computationalism, the classical proponent of the view, would draw parallels from serial processes to how the Turing machine works, as it operates in serial as well, as the central processor of the machine moves from one memory location to the next, when performing operations (Rescorla, 2017). Here evidence of computationalism implemented in models of cognitive science is once again presented. Even though classical computationalists can approve of parallel processes (Rescorla, 2017), processes like these hint that computationalism in its classic sense, might lack explanatory value since its foundations, which is the Turing machinery working in serial, doesn't quite fit with theories of parallel processes and models. This hint, along with other pointers, are the causes of the contention in this essay, namely that the model of computationalism within cognitive science is drifting, and is thus in a stage of revolutionary science. This line of arguments will present itself in the following paragraphs.

The paradigm is drifting and cognitive science is situated at the edge of a scientific revolution

Computationalism is drifting, shifting even, towards something new. How the field has come
Drifting, shifting, twitching
to this point, is as explained through Kuhn's theory the problem-solving behaviour within normal science, where minor or more major problems emerge in the field, and researchers attempt to solve these from the framework of the overarching paradigm. At some point, as the field of cognitive science has come accumulate even more observations and facts, the paradigm becomes challenged. The paradigm is stretched to its limits, and as more observations are crammed under the cover of the paradigm, it will at some point start to crackle, and leave paradigm no longer intact. Cracks in computationalism can be pointed out, through a few examples. One is the apparent replication crisis. A crisis which is grounded in the surprisingly low replication rate in various field, one amongst them is psychology. Since psychology is one of the cornerstones of cognitive science, the replicability crisis influences this field. Investigating the severity of the replication crisis, Open Science Collaboration

(2015) replicated 100 psychological studies in different groups of researchers. The entire study succeeded in replicating merely 36% of the statistically significant results from the original studies, which served as an eye-opener to many fields. The interpretation of the low reproducibility rate of results, as a pointer to cognitive science being in a revolution, can be led by questioning the causes of the crisis. These might be influenced by the pressure that exists within academia to continually publish academic work of significance to preserve or enhance one's career, a pressure which is also coined the term *publish or perish* or the 'publication bias'. Manipulating p-values, changing statistical thresholds and varying methods of analysing data in general, is to be linked with scientific misconduct and questionable research ethics. The debate on replicability crisis can be interpreted as a general crisis for all fields of science that employ suspicious lines of methodological conduct when it comes to treating data. Thus, the entire field of science might be shifting, perhaps towards using other forms of statistical measures, such as probability measures through for example Bayesian statistics, which is closing in on a number of fields (Flam, 2014).

Returning to why the replication crisis might insinuate a change for cognitive science, Kuhn noted himself: "all crises begin with the blurring of a paradigm and the consequent loosening of the rules for normal research" (Kuhn, 1970, p. 84), hence the 'blurring' we experience is this replication crisis, and it serves that the framework of computationalism, might not be adequately explaining observations in the field, and thus there is need for a new paradigm to reinterpret how the field should explain the mind, for the purpose of being able to naturally interpret findings within the new paradigm, without retreating to scientific misconduct.

Computationalism is limited in a number of ways, for example when compared with the rapid advances in artificial intelligence (AI). Computing mental processes have evolved enormously since Turing (1950) proposed the Turing Test to measure machine intelligence. The advances made in the field of AI has hurried along cognitive science and vice versa, as the attempts of implementing human intelligence into the software of machines, is co-dependent on the understanding of mind and intelligence. For example, has decision making through computations of chess been described as search, and been computed through IBM's chess-playing computer, Deep Blue, where search for the optimal move is programmed through hard coded functions. Even though IBM's Deep Blue defeated the reigning chess champion in 1997 (Rescorla, 2017) and made a landmark for computation within AI, the hard coded process through which managed to do so, is a baby-step, compared to the leap made within AI, when Google Deepmind came up with AlphaGo. AlphaGo is a computer program running the ancient Chinese game Go, in which the architecture of the program is made up of a much more advanced search than the one seen in Deep Blue, combined with deep neural networks, inspired by biological models of neurons inside the brain. These neural networks are trained by letting the program play against itself, and through reinforcement learning, the program learns itself the optimal moves from each board configuration (Silver et al., 2016). The way of modelling in terms of neural network, is better specifically grounded in the thought of connectionism, than the classical approach of computationalism. Connectionism aims as well to explain the mind as a computing system, but the manner in which it presents information and explains cognition through biologically inspired models of neural networks (Piccinini, 2009), differs to a certain extent from the general idea computationalism where the focus primarily is to compute higher levels of cognition. Even though that computationalism seems to originally have been introduced as a model of the brain on the grounds of neurological evidence (Piccinini, 2009, p. 515), Some connectionists claim their uniqueness to computationalism, by claiming that "cognition is neural network processing, which is something other than computation" (p. 521). Whilst others argue that computationalism and connectionism have the same explanandum (the mind is a computing system), and thus connectionists should be counted among computationalists. Interpreting the latter through the perspective of Kuhn (1970) and his thought concerning overarching paradigms being incommensurable (p. 103), connectionism could not be a new paradigm of cognitive science. The connectionists model of neural networks have contributed great knowledge and advance, but these models are limited as well, even though they are biologically inspired, the representation of information within the network is of limited capacity, and thus not a sufficient reflection of the brains complexity (Friedenberg & Silverman, 2006). But the focus on presenting knowledge through biological inspired models of neural networks, which connectionism has, does imply that not everything can be explained through the view of strict computations, hence the expansion that connectionism is to the paradigm of computationalism, could infer a need of a new paradigm.

Based on the thought of incommensurability of paradigms, a paradigm which outright challenges the computationalists view, might be presenting itself through the theory of embodiment. Embodiment in cognitive science, or embodied cognition "refers to understanding the role of an agent's own body in its everyday, situated cognition" (Gibbs, 2005, p. 1). This approach has emphasised the role of an agent's body in supporting the workings of the brain, i.e. cognition, a thought in direct contrast to the thought of the body merely being peripheral in understanding the mind, a thought which has been the dominant view in cognitive science and philosophy of mind (Wilson & Foglia, 2017). Evidence of embodied cognition in the field of cognitive science has presented itself in a number of ways, and research surrounding this line of thought is rapidly increasing as well. The evidence presents itself through the research about *mirror neurons*. Mirror neurons have been discovered in the motor cortex of monkeys, as these neurons are active when they perform an action, but also when they see the same action performed. Mirror neurons have been found through fMRI in human brains as well, as the subjects listened to verbs and consequently, the part of the motor cortex that would have produced the action, becomes active (Anderson, 2015, pp. 108-109). Furthermore, research in psycholinguistics found that bodily gestures facilitate understanding of communication and language(Goldin-Meadow & Alibali, 2013; McNeill, 1992), which is also an indicator of embodied cognition. Emphasizing that meaning is represented in systems (perceptual and motor systems) through which we interact with the world, provides an entirely new and radically different view on how information is represented than the one seen in computationalism. Even aspects of AI has pointed out, that intelligence of robots is due in part of its non-computational embodiment (Herath, Kroos, & Stelarc, 2016). As embodied cognition is gaining a footing in cognitive science by being emphasised in the course of many textbooks in the field (Anderson, 2015; Calvo & Gomila, 2008; Gibbs, 2005; Varela, Thompson, & Rosch, 1993), it might be implied that the embodied view could be the next overarching paradigm, or at least, since it is still finding its footing, is a show of development towards a new paradigm.

Conclusion

I believe that the field of cognitive science is on the edge of a scientific revolution. Arguing from the perspective of Kuhn's theory of paradigms, the argument of replicability crisis, expanding the paradigm from computationalism to connectionism, and the theory of embodied cognition are the main arguments for the current revolution in the field. The paradigm of computationalism has had its turn, and as the fields of cognitive science has evolved excessively in understanding the mind through the framework of the computationalists' view, it is yet to acknowledge that there's continually is a great deal of knowledge and phenomena yet to be discovered and researched, and thus there is a need for a new paradigm to do so. If the new paradigm will show itself to be embodiment, then this paradigm will too expire, cause as previously pointed out, any paradigm will only last until is suffers its own crisis.

References

Allchin, D. (1999). Negative results as positive knowledge, and zeroing in on significant problems. *Marine Ecology Progress Series*, pp. 303–305.

Anderson, J. R. (2015). *Cognitive Psychology and Its Implications* (8 edition). New York: Worth Publishers.

Bird, A. (2013). Thomas Kuhn. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy* (Fall 2013). Metaphysics Research Lab, Stanford University. Retrieved from https://plato.stanford.edu/archives/fall2013/entrieshomas-kuhn/

Cahn, S. M., Kitcher, P., Sher, G., & Markie, P. J. (1995). *Reason at Work: Introductory Readings in Philosophy* (3 edition). Forth Worth: Cengage Learning.

Calvo, P., & Gomila, T. (Eds.). (2008). *Handbook of Cognitive Science: An Embodied Approach* (1 edition). Amsterdam: Elsevier Science.

Coplan, J. (2010). Thorndike & Watson: Founding fathers of behaviorism. Retrieved May 27, 2017, from http://www.psychologytoday.com/blog/making-sense-autistic-spectrum-disorders/201008/020-thorndike-watson-founding-fathers

Flam, F. D. (2014, September 29). The Odds, Continually Updated. *The New York Times*. Retrieved from https://www.nytimes.com/2014/09/30/science/the-odds-continually-updated.html

Friedenberg, J., & Silverman, G. (2006). *Cognitive Science - An Introduction to the Study of Mind* (1st ed.). Manhattan College: Sage Publications, Inc.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2013). *Cognitive Neuroscience: The Biology of the Mind, 4th Edition* (4th edition). New York, N.Y: W. W. Norton & Company.

Gibbs, R. W. (2005). *Embodiment and Cognitive Science* (1 edition). Cambridge ; New York: Cambridge University Press.

Goldin-Meadow, S., & Alibali, M. W. (2013). Gesture's role in speaking, learning, and creating language. *Annual Review of Psychology*, *64*, 257–283. https://doi.org/10.1146/annurev-psych-113011-143802

Hansson, S. O. (2017). Science and Pseudo-Science. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy* (2017th ed.). Metaphysics Research Lab, Stanford University. Retrieved from https://plato.stanford.edu/archives/sum2017/entries/pseudo-science/

Herath, D., Kroos, C., & Stelarc. (2016). *Robots and Art: Exploring an Unlikely Symbiosis*. Springer.

Kuhn, T. S. (1970). *The Structure of Scientific Revolutions* (2nd edition, enlarged). Chicago, IL: University of Chicago Press.

McNeill, D. (1992). Guide to Gesture Classification, Transcriotion and Distribution. In *Hand And Mind - What Gestures Reveal about Thought*. Chicago and London: The University of Chicago Press.

Miller, G. A. (1956). The magical number seven plus or minus two: some limits on our capacity for processing information. *Psychological Review*, *63*(2), 81–97.

Miller, G. A. (2003). The cognitive revolution: a historical perspective. *Trends in Cognitive Sciences*, *7*(3), 141–144. https://doi.org/10.1016/S1364-6613(03)00029-9

Open Science Collaboration. (2015). PSYCHOLOGY. Estimating the reproducibility of psychological science. *Science (New York, N.Y.)*, *349*(6251), aac4716. https://doi.org/10.1126/science.aac4716

Piccinini, G. (2009). Computationalism in the Philosophy of Mind. *Philosophy Compass*, *4*(3), 515–532. https://doi.org/10.1111/j.1747-9991.2009.00215.x

Rescorla, M. (2017). The Computational Theory of Mind. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy* (Spring 2017). Metaphysics Research Lab, Stanford University. Retrieved from https://plato.stanford.edu/archives/spr2017/entries/computational-mind/

Serrano, J. I., Castillo, M. D. del, & Carretero, M. (2014). Cognitive? Science? *Foundations of Science*, *19*(2), 115–131. https://doi.org/10.1007/s10699-013-9323-1

Silver, D., Huang, A., Maddison, C. J., Guez, A., Sifre, L., van den Driessche, G., … Hassabis, D. (2016). Mastering the game of Go with deep neural networks and tree search. *Nature*, *529*(7587), 484–489. https://doi.org/10.1038/nature16961

Treisman, A. M. (1964). SELECTIVE ATTENTION IN MAN. *British Medical Bulletin*, *20*(1), 12–16. https://doi.org/10.1093/oxfordjournals.bmb.a070274

Turing, A. M. (1950). Computing Machinery and Intelligence. *Mind*, pp. 433–460.

Varela, F. J., Thompson, E., & Rosch, E. (1993). *The Embodied Mind* (Vol. 1st). Massachusetts Institute of Technology.

Wilson, R. A., & Foglia, L. (2017). Embodied Cognition. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy* (Spring 2017). Metaphysics Research Lab, Stanford University. Retrieved from https://plato.stanford.edu/archives/spr2017/entries/embodied-cognition/