Proceedings of the Annual Meeting of the Cognitive Science Society

Title

Exploring the Reality of the Knowledge Level: Pragmatism Embodied

Permalink

https://escholarship.org/uc/item/3657m2rp

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 40(0)

Authors

young, Jeremy T
West, Robert L

Publication Date

2018

Exploring the Reality of the Knowledge Level: Pragmatism Embodied

Jeremy T. Young (jeremyyounggrad@gmail.com)
Institute of Cognitive Science, Carleton University, Ottawa, Ontario, Canada,
Robert L. West (robert_west@carleton.ca)
Institute of Cognitive Science, Carleton University, Ottawa, Ontario, Canada

Abstract

Allen Newell's Knowledge Level theory is a philosophical position on the reality of knowledge that is best understood through the lens of Pragmatism--specifically, the view that the practical effects of general concepts are indelibly linked with the reality of those concepts. Consequently, the reality of the knowledge level is context-dependent. Newell's theory reduces the complexity of analyzing every mechanism behind intelligence systems by abstracting away details irrelevant to predicting behavior and, as such, is more important than ever in light of current challenges in cognitive science.

Keywords: Knowledge Level; Knowledge Representation; Cognitive Modeling; Cognitive Architectures; Inter-theoretic Levels; Agency; Behavioral Prediction.

Introduction

Although talk of 'levels' is rampant in cognitive science, Newell's (1982) theory of levels is distinct in that he argued that his levels actually existed as realities in the world. That is, Newell viewed systems levels as an ontology rather than an epistemology. Newell clearly stated, "Computer systems levels are a reflection of the nature of the physical world…they are not just a point of view that exists solely in the eye of the beholder" (Newell, 1982, pp.12-13).

Newell's view that systems levels represent ontological realities in the natural world is perhaps most challenging when applied to his idea of the Knowledge Level (KL), because it implies that 'knowledge' (belief) has a real, ontological existence. Newell's KL theory is an evolution of several ideas that have wound their way through the history of the study of the mind but in particular it shares a great deal in common with Daniel Dennett's Intentional Stance (IS) (Dennett, 1987) and Karl Popper's Rationality Principle (RP) (Popper, 1994).

Newell used the term, Rationality Principle, to describe the operating mechanism behind the KL. According to Newell, the rationality principle states that an agent will use the knowledge it has of its environment to achieve its goals (Newell, 1982, p.17). Although, as far as we can see, Newell did not reference Popper, he was likely referring to Popper's Rationality Principle as his description seems identical.

In terms of the IS, Newell was more clear and stated that, "The intentional stance corresponds to the knowledge level", however, "The intentional stance is unalterably separated from the physical … there is little doubt that both Dennett and myself are reaching for the characterization of exactly the same class of systems…in particular the role of rationality is central to both" (Newell, 1982, p.34). According to Newell, "To treat a system at the knowledge level is to treat it as having some knowledge, some goals, and believing it will do whatever is within its power to attain its goals, in so far as its knowledge indicates" (Newell, 1982, p.13). Similarly, Dennett explained that in the IS, "You decide to treat the object whose behavior is to be predicted as a rational agent; then you figure out what beliefs [knowledge] that agent ought to have, given its place in the world and its purpose…then you figure out what desires it ought to have…and finally you predict that this rational agent will act to further its goals in the light of its beliefs/knowledge (Dennett, 1987, p.17).

All three theories outline methods for predicting the behavior of intelligent agents by weighing the agent's goal(s), its beliefs about its environment (knowledge), and applying the rationality principle to determine the (bounded) optimal path to the goal(s). However, although Popper acknowledged that the RP allowed the social sciences to make accurate predictions, he maintained that the RP was an epistemology and, based on this, relegated Cognitive Science to the pseudo-sciences. Popper was, consequently, criticized for the seeming contradiction that non-sciences could make accurate predictions (Popper, 1994). Dennett's position is even more confusing. While he resists the idea that the IS is merely an epistemology, he seems unwilling to fully commit to an ontological status (see Bechtel, 1985, for more discussion). In contrast, Newell avoids these philosophical difficulties by treating the KL as real because, "Distinguishing this level [the KL] leads to a simple and satisfactory view of knowledge and representation...it dissolves some of the difficulties and confusions that we have about AI" (Newell, 1982, p.13).

The KL constitutes a philosophical position on Knowledge. However, Newell was not a philosopher and did not take a traditional philosophical approach to laying out his ideas. Nevertheless, we argue that Newell's KL represents an important philosophical position best viewed through the lens of Pragmatism.

The Metaphysical Status of Levels

Analyzing Newell's levels requires an understanding of how levels are employed in cognitive science. Here we briefly present the specific issues that help frame Newell's position (for more detailed accounts of the use of levels see: Kersten et al., 2017; Bechtel & Anderson, 2007; Churchland, 1986; Nickles, 1973; and Wimsatt, 1976.).

Epistemology

Marr's Tri-Level Hypothesis and Dawson's slightly modified version of Marr's system are good examples of the epistemological use of levels in the study of cognition (Marr & Poggio, 1977; Marr, 1982; Dawson, 2013). Marr's Tri-level Hypothesis separates all information processing aspects into one of three levels: Computational, Algorithmic, and Implementational ordered from top to bottom (Marr, 1982). Dawson's system is the same as Marr's but inserts an Architectural level between the Algorithmic and Implementational levels (Dawson, 2013, p.36). Emphasizing the epistemic nature of these level systems, Dawson writes "Levels do not attempt to explain the nature of information processing devices, but instead provide an epistemology—a way to inquire about the nature of the world" (Dawson, 2013, p.53). This is *not* how Newell's levels should be understood.

Ontology

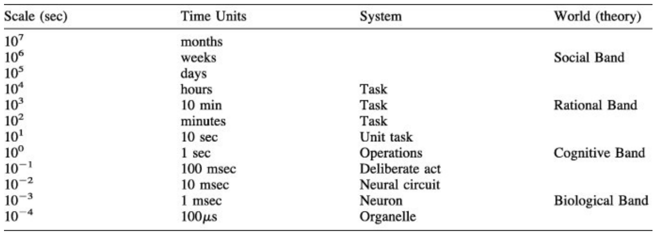
The second way that levels are employed in cognitive science is ontologically. Newell uses the engineered system levels in computers as evidence that system levels can physically exist (Newell, 1982, p.11-12, Causey, 1977). In Newell's theory, each level emerges from the level immediately below it, as in computers (Newell, 1982, p.10). According to Newell, "A system level is a property of nature, and not just something in the head of the observer" (Newell, 1990, p.118). The claim that brains are built in this way is based on Simon's theory of the evolution of hierarchical systems, in which he used the parable of the two watchmakers to explain why evolution tends to produce hierarchical structures (Simon, 1969, pp.188-189). It is also connected to the Physical Symbol System Hypothesis that Newell and Simon developed, which is a physically grounded system rooted in Frege, Whitehead, and Russell's research on logic, and thus ontological in nature (Newell, 1982, p.11; Newell & Simon, 1976, pp.85-88).

Vocabulary

Some authors take a position on levels that goes beyond epistemology but does not commit fully to an ontological position. Patricia Churchland theorized that the vocabulary and laws of higher level theories provide a more efficient means of referring to far more complex processes at the lower levels (Churchland, 1986)—a benefit Dennett noted about his IS (Dennett, 1987, pp.33-35). Likewise, Pylyshyn (1984) distinguishes levels in terms of how they are articulated.

Newell used levels to refer to the actual levels and bands to refer to theoretical language appropriate for describing levels (see Table 1). Following common practice, we will continue to refer to the neural level, the cognitive/symbolic level, etc., but it is important to note that these potentially refer to multi level systems.

Table 1. Newell's levels and bands



Scale (sec)	Time Units	System	World (theory)
10^7	months		
10^6	weeks		Social Band
10^5	days		
10^4	hours	Task	
10^3	10 min	Task	Rational Band
10^2	minutes	Task	
10^1	10 sec	Unit task	
10^0	1 sec	Operations	Cognitive Band
10^{-1}	100 msec	Deliberate act	
10^{-2}	10 msec	Neural circuit	
10^{-3}	1 msec	Neuron	Biological Band
10^{-4}	$100 \mu s$	Organelle	

Context and Boundary Conditions

As noted in Kersten et al (2017), Bechtel and Hamilton (2007) argue for a third position, transcending the epistemology-ontology dichotomy. They assert that cognitive constructs, such as symbols or rules, should be considered as real ontological entities when their boundary conditions are met, where boundary conditions refer to situational and neural constraints that result in the deployment of cognitive structures that function in a consistent and predictable way. Similarly, Newell states, "The medium is realized by state-like properties of matter, which remain passive until acted upon by the level's components" (Newell, 1982, p.16). This suggests that Newell's sense of reality is consistent with that of Bechtel and Hamilton. In addition, the KL can be viewed as providing the boundary conditions of a given problem space or task. In practical/real world problems, this amounts to the facts of the agent's physical environment. In intellectual/scientific problems, it amounts to the logical/conceptual constraints imposed by the specific domain of the problem set.

Newell's distinction between computer system levels and levels in scientific descriptions clarifies what he meant by asserting the reality of the KL. He explained that a computer systems level "does not provide a general closed description of an entire universe, which is what we generally expect (and get) from a level of scientific description in physics or chemistry" (Newell, 1980, p.12). Instead, computer systems levels such as the KL describe the dynamic relation (series of evolving relational states) between a system/agent and its environment and do not describe the environment in its totality. Dennett noted that organisms continuously mirror their environments and representations of the environment are implicit in the system's organization (Dennett, 1987, p.31). Consequently, computer systems levels are approximations/abstractions and are realized in the physical world only to various degrees and within specific boundaries of a given environment.

Knowledge as the Medium

Newel explained that all levels are based on a *medium* that is to be processed (Newell, 1982, p.10). Here, we feel that Newell's choice of the word medium was unfortunate, as it may suggest something that is immediately physical, such as clay for a sculptor or paint for a painter. Neurons have come to be accepted as the foundational medium from which the brain is built. When Newell states that knowledge—which is made up of symbols—is the medium for the KL it is often interpreted as giving symbols some sort of mysterian existence, independent of neurons. However, this is not what was meant. The medium of knowledge is ultimately an emergent product of neurons, just as neurons are ultimately a product of chemistry. Newell used the term medium to mean physically instantiated structures that reliably function in certain ways when their boundary conditions are met.

In the case of the medium of knowledge, its ultimate value lies in the fact that the physical symbols being processed are imbued with meaning—i.e. serve as representations for objects in the physical world (Newell & Simon, 1976, p.89). The meaning is the medium for the KL, not the way the meaning is represented at the cognitive level.

This way of dividing the levels means that questions of representation and grounding apply to the cognitive level, not the KL. This is extremely important for AI as it allows for a divide and conquer, top down design strategy, starting from a specification at the KL, followed by issues of how to represent the knowledge, and so on downwards. However, with human beings we are confronted with the problem of how representation actually works when we probe below the KL. For example, the fact that we can answer a question can be predicted by the fact that we know the answer (KL), but the retrieval time for the answer depends on the details of the representation and retrieval mechanisms (cognitive level).

With this understanding, we argue that Newell's ontological levels are not incommensurate with the use of epistemological levels. For example, once we accept that medium does not need to refer to neurons we can apply Dawson's (2013) epistemological levels to each of Newell's ontological levels. That is, each of Newell's ontological levels can be understood in terms of a medium, an architecture, an algorithm, and a computational purpose.

The Cognitive Level

Before discussing the KL, we will first briefly discuss the cognitive level as it provides the foundations for accurately understanding the KL. The cognitive level is assumed to be based on neural structures that allow the encoding, storage, transportation, and alteration of neural representations (similar to a computer OS) (Newell, 1982, 1990). A cognitive architecture, such as SOAR or ACT-R specifies mechanisms based on these functions, and combinations of these functions.

A representation could correspond to a word, but it could also be an internal, non-linguistic code. Newell defined "symbols" in terms of *distal access* (Newell, 1994, p.132). This definition means that whenever a mechanism sends a communication to another mechanism, the communication is symbolic. Effectively, a symbol is a packet of meaningful information (encoded at the cognitive level) and transported within the system.

Knowledge is not to be found within the cognitive level, instead it is an emergent property of the cognitive level and constitutes the medium for the KL. Cognitive mechanisms perform actions such as, *if representation A matches representation B then send representation A to location X,* and are unaffected by the meaning of the representations.

Following from Betchel and Hamilton's (2007) concept of real, cognitive mechanism exist when they are being used (i.e., when their boundary conditions are met) and can be considered "inert" as Newell and Simon described them, when they are not used (Newell & Simon, 1976). Newell took this one step and further hypothesized the existence of an integrated system of cognitive mechanisms, which exists as a cohesive systems level, built on functional neural structures. Newell was clear that this was a hypothesis that needs to be empirically investigated (Newell, 1990). It is not a rational argument that the cognitive level must exist and must take a particular form. Although Newell did propose a particular theory describing the cognitive architecture (SOAR), proposed theories about the cognitive level (cognitive architectures) are informed guesses about its actual form.

Also, it is possible that some parts of the brain are *not* organized so as to produce a cognitive systems level and/or that other types of systems levels exist (Chomsky, 2016). Chomsky's idea of a language module would be an example of a different type of systems level (likewise Chomsky seems to treat symbols as coherent physical entities). Minimally, Newell's hypothesis amounts to an empirical claim that a cognitive systems level exists somewhere in the brain and contributes to determining thought and action.

The SOAR architecture and other cognitive architectures influenced by Newell's ideas (such as ACT-R) are often criticized for using overly simplistic symbolic structures and ignoring problems related to representation, meaning, context, and grounding. However, we argue that this is due to a philosophical misunderstanding. The knowledge entered into these architectures is derived from a KL analysis of the task. Modelers translate this knowledge directly into symbols for use as representations within the cognitive architecture. This practice can be justified by arguing that it is sufficient to use only the parts of the symbolic representations that have influence in the task, as determined by the KL analysis. This sidesteps complex issues related to representation, but it means that symbols created in this way should be understood as task-bound simplifications. Whether this practice is legitimate ultimately depends on how the human cognitive system actually represents information. However, our point is that the logic for it flows from Newell's concept of the KL as a separate level.

The Knowledge Level

Within the boundaries of the KL, we can analyze an agent's knowledge of its environment (beliefs), its goals (desires), and use the principle of rationality to determine the most probable and efficient path that an agent will take through the problem space to reach its goals—this path constitutes the agent's (bounded) optimal behavior. Within the KL, representations are the data structures holding the world knowledge that will be processed into a form that makes the solution available-the first data structure represents the problem (to include a goal), the second represents beliefs (Newell, 1982, p.2). Actions within the KL are those processes used to affect an agent's internal state or its external environment in such a way that it moves closer to achieving its intended goal—i.e. through the problem space. Similarly, Dennett noted that changes in an agent's environment result in chances to its internal state (Dennett, 1987, p.31).

Newell viewed the KL as a philosophical claim within the field of Cognitive Science, "the analysis of knowledge has a long philosophical history …it has a continuation in cognitive science…that analysis is [about] what it means for a system to have knowledge" (Newell, 1994, p.41); "What cognitive science needs … is a concept of knowledge that is used to describe and predict the response of functions of [an intelligent] system" (Newell, 1994, p.46).

Newell's philosophical justification for the ontological status of the KL is simply that, as in AI, it could be built on the level below, "as just another level in the hierarchy …, there is nothing special about the knowledge level, in any foundational or philosophical sense. (Newell, 1994, p.49)

Newell's Computational Work as Philosophy

Newell wrote little on his philosophical beliefs, but he and Simon created a normative model of intelligence, the Problem Space (Newell, 1972), and Newell co-designed one of the first cognitive architectures, SOAR (Laird, Newell, Rosenbloom, 1987). We argue that Newell's philosophical beliefs are implicitly embodied in these two projects. If one looks at Newell's research on problem space and the SOAR architecture, a clear central theme arises—namely that all action is defined in service of a goal (Newell, 1982; Newell, 1990). This view is consistent with pragmatism's definition of truth/reality. Newell and Herb Simon explained, "All information processed by computers is in the service of ends [goals] and we measure the intelligence of a system by its ability to achieve stated ends in the face of variations, difficulties, and complexities posed by the task environment" (Newell & Simon, 1976). Newell saw the goal-oriented nature of production systems as the means for creating this type of intelligence in the SOAR architecture.

Briefly, problem spaces interpret problems as having a starting node (or state), a goal node, and interviewing nodes that bring the agent from the starting node to the goal node. The agent traverses the nodes by making decisions that determine actions taken based on the information available at the current node which results in taking it to a subsequent node. However, at each node there are typically several different possible actions leading to different nodes. Problem-solving is therefore understood as knowing what to do next based on the information at hand (i.e. the current node). The SOAR architecture traverses problem spaces by using production ('if-then') rules. At each node, only the productions that match the information associated with the node can "fire" and execute the actions required to move to another node. Each production rule is associated with a specific utility value. Experts have finely-tuned utility values such that in the event that more than one production matches the firing conditions the highest utility production is chosen and the agent will move to the best, next node leading to the goal. If no production matches, then the system has reached an impasse. To deal with this, SOAR will compare the information associated with the node to other nodes it has encountered in the past, select the most similar, and see if there is a production for that. In this way SOAR can make decisions in circumstances it has not encountered before (draw inferences) and learn from the feedback. This is consistent with Peirce's characterization of reasoning, "the object of reasoning is to find out, from the consideration of what we already know, something else which we do not know" (Peirce, 1978, p.7).

Considered in such a light, it becomes clear how Problem Spaces and SOAR are computational expressions of the fundamental beliefs of Pragmatic Philosophy. Put another way, if we accept the Pragmatist account of the human mind and apply Marr/Dawson's levels, then navigating to a goal is the computational problem, Problem Space is the algorithm, SOAR is the architecture, and neural systems for storing and processing symbolic information is the medium or physical instantiation.

Pragmatism Embodied

We argue that to fully understand Newell, he needs to be seen as a Pragmatist. However, because Pragmatism has taken on many guises over the years, before we begin we must clarify what we mean by the term. While we do not completely disagree with Fodor's criticism of pragmatism in cognitive science (see Fodor, 2008, p.5.), we see a high degree of divergence between pragmatism as it is characterized in the works to which he refers and Pragmatism's original articulation. Although references to pragmatism abound in cognitive science literature, they have wandered far from the fields original principles. This degradation of the core tenants of Pragmatism began almost immediately, forcing some of its founders—such as Charles Sanders Peirce and Ferdinand Canning Scott Schiller—to rebrand their views to maintain the clarity and integrity of their terms and principles (Peirce, 1978; Schiller, 2005). With this in mind, the Pragmatism discussed here will be that of early Pragmatists as opposed to these far-ranging subsequent interpretations. Space precludes a full historical discussion of Pragmatist philosophy; instead, we focus on pragmatic elements essential to understanding the KL.

The Real Furthers our Goals

For both Newell and the Pragmatists, the real is that which aids in the accomplishment of our goals, which, in turn alter the physical world**.** Similar to the force of gravity—which cannot be seen, touched, or heard, yet exerts a force on physical objects—the force of knowledge directly impacts the physical world. This view is consistent with Peirce's Pragmatic maxim: "Our idea of anything *is* our idea of its sensible effects…consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have…then, our conception of these effects is the whole of our conception of the object" (Peirce, 1978, p.31). Within this perspective, the practical effects of a belief or knowledge concept are indelibly linked with that concept's reality. Consequently, the verifiable effects arising from physical instantiations of knowledge concepts conceived within the KL—i.e. buildings arising from blueprints, lives saved through medical breakthroughs, etc.—justify the level's reality. That is, the reality of the KL is evident by the real solutions its general concepts provide to human problem-solving and the resultant actions that reshape the physical world in the furtherance of human goals. Peirce asked, "What do we mean by real…the real, then, is that which, sooner or later, information [knowledge] and reasoning would finally result in" (Peirce, 1978, p.247).

Knowledge is Acquired by Doing

Peirce also shared Newell's experiential perspective that we acquire knowledge as participants—by doing or through experience, as the Empiricists endorsed. Peirce argued that knowledge is an activity, not a spectator sport—i.e. it is both the activity and the product of the activity. This view is remarkably similar to the concept of forward engineering that fueled Newell's artificial intelligence research, where "doing" often comes before and enables "understanding". Peirce noted that this is "Because we are part of the living world, and it is primarily through the pursuit of survival [humankind's fundamental goal] that we acquire knowledge…the most valuable thing about knowledge is its explanatory power" (Peirce, 1978). Thus, we see self-preservation as the original goal setting the chain of our reasoning and behavior in motion.

Everything Experiencable is Real

Other Pragmatists also provide support for the existence of the KL. William James outlined his famous metaphysical first principle as "Everything real must be experienceable somewhere, and every kind of thing experienced must somewhere be real" (James, 2000, p.27). As an idea appears in our mind, we have an experience of it. We turn it over and over to understand it, and we shape it to enhance it and make it better fit into our broader view of the world. James believed that knowledge (belief) was *true* only to the extent that in establishing satisfactory relationships with all other aspects of one's experience—that is, their truth value was dependent on their consistency with the larger body of our world knowledge (2000).

Knowledge Transforms the Physical World

Schiller employed the Protagorean maxim that "man is the measure of all things" to make Peirce's Pragmatism more human-centric (Schiller, 2005, p.12). He characterized Humanism as "the perception that the philosophical problem concerns human beings striving to comprehend a world of human experience by the resources of human minds" (Schiller, 2005, p.12). This supports perspective of embodied cognition as well. Schiller argued that the power of cognition actually transforms the physical reality of the world and consequently our desires (goals) and ideas (beliefs) are real by virtue of their impact on the world (Schiller, 2005). Schiller explained that Pragmatism was "a special application of Humanism to the theory of knowledge" (Schiller, 2005, p.16). Our use of the KL is one of the inherent facets of human nature—no other animal can match our urge to continually reshape our environment. Schiller's "human experience" is precisely the type of data to which Newell refers as knowledge in the systems he, Dennett, and Popper all discuss to varying degrees. Despite being written in 1907, the applications of Schiller's method to the study of human cognition and artificial intelligence—specifically cognitive modeling—are abundant.

The Knowledge Level in the Scientific Method

Recognizing the limitations of humankind's access to an objective truth, Pragmatists viewed 'truth' as a process of incrementally enhancing the accuracy of our explanations to come closer and closer to absolute truth without ever fully reaching it. Schiller noted, "All testing of 'truth' is, therefore, fundamentally alike…it always implies an experiment…and it always ends in a valuation" (Schiller, 2005, p.7). Compare this with Popper's theory on scientific progress, "Science always begins and ends with problems…the progress of science lies, essentially, in the evolution of its problems" (Popper, 1994, p.155). Popper viewed the evolution of problems as the sharing, empirical testing, analytical debate, and the final collective assignment among the scientific community of a valuation of one theory over another based on its practical ability to explain more than the previous theory. Where Schiller and Popper diverged was in Popper's view that "scientific problems [searches for truth] are preceded, of course, by pre-scientific problems, and especially practical problems" (Popper, 1994, p.156). Schiller viewed all such searches for truth as having a practical nature as he argued that "all mental life is purposeful" (Schiller, 2005, p.5). The KL is the space in which this collective evolution of science takes place.

Context Determines Truth

Similar to Bechtel and Newell, Pragmatism too defined all truth/reality as dependent upon the context or boundary conditions of a situation. Peirce said, "there are phenomena within our own minds, dependent upon our thought, which are at the same time real in the sense that we really think them…but though their characters depend on how we think them, they do not depend on what we think those characters to be…thus a dream has a real existence" (Peirce, 1978, p.36). Schiller argued that 'abstract' truths were not fully truths because truth was essentially dependent upon context (Schiller, 2005, p.8). In the case of the KL, the context amounts to the boundary conditions of the agent's environment or those of the problem set at hand. The essence of the Pragmatic method, according to Schiller, is that "the meaning of a rule lies in its application…it rules, that is, and is true, within a definite sphere of application [within certain boundary conditions], which has been marked out by experiment" (Schiller, 2005, p.9). Schiller explained for a statement to be true, it had to be tested by being applied, only after which could we determine its real meaning and what conditions must be met for it to be real/true (Schiller, 2005).

Conclusion

The ontological commitment of Newell's KL theory offers a common scientific framework for integrating research on how agents employ knowledge to accomplish goals in rationally-consistent ways. Understanding this theory requires viewing computer systems levels as approximations, which are realized physically only to various degrees and within the boundaries of specific environments. Knowledge concepts within the KL are medium-agnostic data structures but are always physically-instantiated and are ultimately emergent products of neurons. Moreover, the reality of knowledge resides in the fact that the physical symbols of which it is comprised are inert (do not stand for anything) while undergoing processing, but subsequently imbued with meaning that allows them to serve as representations of objects the physical world (Newell & Simon, 1976).

The KL theory permits efficient abstraction of complex cognitive mechanisms and representations while maintaining a high degree of accuracy in predicting behavior. Newell's perspective allows the mapping of ontological levels onto epistemologies to further understanding of cognition. Pragmatism supports Newell's ontological commitment to the KL and provides insights for broader issues in current cognitive science and AI research.

References

Bechtel, W. (1985). Realism, Instrumentalism, and the Intentional Stance. *Cognitive Science*. 9, 473-497.

Bechtel, W., & Hamilton, A. (2007). T. Kuipers (ed.), From *Philosophy of Science: Focal Issues* (Vo. 1 *Handbook of the Philosophy of Science*). New York: Elsevier.

Causey, R. (1977). *Unity of Science*. Dordrecht, Holland: Reidel Publishing Company.

Chomsky, N. (2016). *What Kind of Creatures are We?* New York, NY: Columbia University Press.

Churchland, P. S. (1986). *Neurophilosophy: Toward a Unified Science of Mind-Brain*. Cambridge, MA: MIT Press/Bradford Books.

Dawson, M. R. W. (2013). *Mind, body, world: Foundations of cognitive science.* Edmonton, AB. AU Press.

Dennett, D. C. (1987). *The Intentional Stance.* Cambridge, Massachusetts: The MIT Press.

Fodor, J. (2008). *LOT 2: The Language of Thought Revisited*. Oxford, UK: Oxford University Press.

James, W. (2000). *Pragmatism and Other Writings*. New York, NY: Penguin Books. (Originally published in 1907.)

Kersten, L.; West, R; & Brook, A. (2017). Leveling the Field: Talking levels in cognitive science. *Cognitive Science*. 9, 473-497.

Laird, J.; Newell, A.; & Rosenbloom, P. (1987). SOAR: An architecture for general intelligence. *Artificial Intelligence*, vol. 33, 1-64.

Marr, D. (1982). *Vision*. San Francisco, CA: W.H. Freeman.

Marr, D., & Poggio, T. (1977). From understanding computation to understanding neural circuitry. *Neurosciences Research Bulletin,* 15, 470-488. San Francisco, CA: W.H. Freeman.

Newell, A. (1972). *Human Problem Solving*. Englewood Cliffs, NJ: Prentice Hall.

Newell, A. (1982). The Knowledge Level. Pittsburgh, PA: Carnegie Melon University, Department of Computer Science Research Showcase series.

Newell, A. (1990). *Theories of Unified Cognition*. Cambridge, MA: Harvard University Press.

Newell, A., & Simon, H. (1976). Computer Science as Empirical Inquiry: Symbols and Search. In J. Haugeland (Ed.), *Mind Design II: Philosophy, Psychology, and Artificial Intelligence* (1997). Cambridge, MA: The MIT Press.

Nickles, T. (1973). Two concepts of intertheoretic reduction. The Journal of Philosophy., 70, 181-201.

Peirce, C. S. (1978). *The Philosophy of Charles Sanders Peirce: Selected writings*. Buchler, J. (Ed). New York, NY: AMS Press.

Popper, K. (1994). *The Myth of the Framework*. New York, NY: Routledge Publishers.

Pylyshyn, Z. (1984). *Computation and Cognition: Toward a Foundation of Cognitive Science*. Cambridge, MA: MIT Press.

Schiller, F.C.S. (2005). *Studies in Humanism*. Boston, MA: Adamant Media Corporation-Elibron Classics Series. (First published in 1907).

Simon, H. (1969). *The Sciences of the Artificial*. Cambridge, MA: MIT Press.

West. R. L., & Young, J. T. (2017) Proposal to add Emotion to the Standard Model. Association for the Advancement of Artificial Intelligence (AAAI) 2017 Conference Proceedings.

Wimsatt, W. C. (1976). Reductionism, levels of organization, and the mind-body problem. In I. Savodnik (Ed.), *Consciousness and the Brain: A Scientific and Philosophical Inquiry*. New York: Plenum Press.