STUDIA UBB. PHILOSOPHIA, Vol. 66 (2021), 3, pp. 193-218
(RECOMMENDED CITATION)
DOI:10.24193/subbphil.2021.3.09

AFFORDANCE BASED FRAMEWORK OF HUMAN PROBLEM SOLVING: A NONREPRESENTATIONAL ALTERNATIVE

PANKAJ SINGH[1]

ABSTRACT. Problem solving is a crucial higher-order thinking ability of humans. Humans' ability to solve problems is a critical higher-order thinking ability. Mathematical problem solving, analogical problem solving, complex problem solving, situated problem solving, and so on are all examples of problem solving. Furthermore, distinct types of research analysis, models, and theories are based on the mechanisms and elements involved in diverse problem-solving types. The conventional approach to understanding human problem solving is a representation-laden description, which is similar to most cognitive explanations of psychological processes. On the other hand, the paper goes beyond representational theories and models to investigate nonrepresentational and situated aspects of human problem solving. Problem solving is a crucial higher-order thinking ability of humans. The paper is a rudimentary attempt to present a nonrepresentational, Affordance-Situation-Attunement (ASA) framework of human problem solving. The aim is to invoke ASA as an alternative framework, in contrast with the dominant representational explanation of human problem solving. The aim is not to disparage the representational theories and models of problem solving but to contribute a nonrepresentational working framework and elements for highlighting the situated nature of human problem solving.

Keywords: Problem solving, affordances, embodied cognition, situated cognition, ecological psychology

1. Introduction

Humans are often involved in getting themselves out of different problematic situations. Philosopher Karl Popper suggested "All Life is Problem Solving."[2] From mundane daily activities like thinking about what to eat, what to wear in the morning

1 Assistant Professor, School for Life (SFL), University of Petroleum & Energy Studies (UPES), Energy Acres Building, Bidholi, Dehradun- 248007, Uttarakhand, India. Contact: Mob no. +91 8795530965; pankajsingh.028@gamil.com.

2 Karl Popper, *All life is problem solving* (London: Routledge, 2013.), 99.

©2021 SUBB Philosophia. Published by Babes-Bolyai University/Cluj University Press.
This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

after waking up to struggles of rocket science to unravel the mysteries of the universe, all are problems in a way requiring solving. In the local scope of term problem, people use it to describe their personal problems like overcoming a heartbreak, finding a job, ways of investing money, completing projects, and so on so forth; at the global level, people attempt to address issues like global warming, Israel-Philistine dispute, equality in pay, human and animal rights, and similar matters. Considering problem and problem solving under one umbrella definition is problematic because it is both subjective and context-oriented, differs from person to person, situation to situation. So, Popper's characterization of problem solving as a lifelong endeavor is plausible.

Despite highly vague usage of the term problem, Karl Duncker's definition of the problem, which consists of starting few lines of his seminal work, is still one of the most cited in the literature of problem solving,

> A problem arises when a living creature has a goal but does not know how this goal is to be reached. Whenever one cannot go from the given situation to the desired situation simply by action then there has to be recourse to thinking. By action, we here understand the performance of obvious operations.[3]

For Duncker, a problem mainly required thinking and performing appropriate operations to move from problem situation (given situation) to solution (desired situation). For example, someone is getting ready for the office but cannot find one's favorite shirt to wear. The given situation is the availability of one's shirt; the desired situation is finding it. One needs to perform many actions to move from a problematic situation to a solution situation. One's very first resort could be just sitting there and thinking about trying to figure out the shirt's location; shuffle between the other clothes in the closet to get a glimpse of it; ask one's wife to help one out in finding one's shirt. Any of these actions are the performance of apparent operations that can lead to the desired situation. In the same vein, other problems can be broken into descriptions of goals and operations. For example, a teacher trying to design a new course curriculum, an athlete trying to achieve a world record, chess players trying to best one another, a novelist contemplating on next project, philosophers pondering over the unanswerable questions, computer engineer trying to debug a system, or theoretical physicist scribbling formulas to propose a theory of everything. Somebody can apply Duncker's proposal of goal, different situations, and required operation to any of such examples. Dunker's characterization of problem solving in terms of goals was picked up and developed by cognitive science researchers in problem solving. The research was the outcome of the cognitive revolution which took place during the 1950s. Advances in linguistics,

[3] Karl Duncker, "On problem-solving", trans Lynne S. Lees. *Psychological monographs* 58(5), 1945, 1.

neuroscience, and especially the emergence of programmable computers inspired the cognitive revolution. According to Robertson, "the arrival of the digital computer allowed cognitive scientist to describe human behavior in terms of the encoding, storage, retrieval, and manipulation of information, and to specify the mechanism that presumed to underline these processes."[4]

Consequently, functionalism became the dominant theory in the philosophy of mind and cognitive science. Pioneers of artificial intelligence such as Herbert Simon, Marvin Minsky, Allen Newell, and John McCarthy also pursued the model of information theory and functionalism. Linguists like Noam Chomsky rejected behaviorism based on his assumption of mental grammar consisting of rules. Rapid advancements in the field of neuroscience also helped in unraveling the mysteries of mind and brain. Emphasis on the role of mental representation is the hallmark feature of cognitive science. Representational models to understand mind and cognition led researchers' focus on the study of brain processes, which assumed the center of representation and symbol manipulation. The current form of research in problem solving started to shape the experiments and research by Herbert Simon and Allen Newell in the 1960s. They developed the problem solving as Information Processing Theory of Problem Solving (IPTPS).[5] The representation-based IPTPS became the basis for most of the subsequent research on problem solving, setting the information processing model the most prominent approach, "which continues to be at the heart of contemporary theorizing about problem solving."[6] Section 2 present the traditional IPTPS and objections to the model. Next, section 3 addresses the objections to IPTPS and proposes a nonrepresentational Affordance-Situation-Attunement (ASA) model of conceptualizing human problem solving. Section 4 concludes the paper with an implication to the possibility of a full-fledged ecological theory of problem solving.

2. Traditional Framework and Explanation

Philosophy dominated the study of the mind before the rise of psychology in the 19th century. Until the 20th century, introspection of conscious states and processes was an established method of psychological experiments. Soon after the advent of experimental psychology, behaviorism took center stage. Behaviorism

---

4 Ian, Robertson, *Problem solving: Perspectives from cognition and neuroscience* (New York: Routledge, 2016), 12.

5 Allen Newell and Herbert Alexander Simon, *Human problem solving* (Englewood Cliffs, NJ: Prentice-hall, 1972).

6 Kevin Dunbar, "Problem solving," in William Bechtel, and George Graham (eds.), *A companion to cognitive science* (Oxford: Blackwell Publishing Ltd, 1998), 290.

focused its attention on examining the relationship between stimuli present in the environment and behavioral responses to the stimuli. Behaviorists believed that the study of intermediary processes between stimulus and response is futile due to the limitation of mediating processes being unobservable. They were interested in the experimental study of observable stimulus and response. Inside the brain was considered a black box, not a subject matter of psychological research. Philosopher Wilfred Sellar tried to come up with a loose qualification for being a behaviorist, "someone who insist on confirming hypothesis about psychological events in terms of behavioral criteria."[7] The core claims of behaviorism gave rise to the trial and error method of problem solving. The trial and error approach of problem solving is based on repeated and varied attempts. Such an approach is an unsystematic method of problem solving. It does not require any insight, theory, or organized methodology. The advantage of the trial and error method is that one does not need to rely upon specific knowledge to solve a problem. On the other hand, the trial and error method is often disadvantageous because it is tedious, time-consuming, and monotonous.

During the dominant period of behaviorism, the Gestalt movement was supplying insights to conceptualize human behavior and the mind as a whole. Gestalt psychology is a pursuit of understanding the mechanism responsible for acquiring and maintaining a meaningful, holistic perception of the chaotic world around the organism. *Gestalt* in Gestalt psychology is a German word, which in English has multiple meanings, like shape, form, figure, and frame. However, the word Gestalt is often best characterized by the famous phrase, "the whole is greater than sum of its parts", which is a wrong translation, as Kurt Koffka meant "the whole is something else than the sum of its parts."[8] Rather than fixating on stimulus and response, like behaviorists, gestalt psychologists focused their attention on understanding the organization of cognitive processes. The gestalt approach to problem solving points towards the importance of the representation of elements of the problem. Gestaltists were the first to describe the existence of *insight, illumination, or a-ha experience,* not only in humans but also in animals. However, gestalt psychologists fail to specify the exact mental mechanism of phenomena of restructuring and insight.

Despite enjoying popularity and authority for almost four decades (from the 1900s to 1940s), with the advancement of neuroscience science, and cognitive revolution, the influence of behaviorism faded away—the cognitive revolution in

---

[7] Sellars, Wilfrid, "Philosophy and the scientific image of man," in Robert G. Colodny (ed.), *Science, perception and reality* (Pittsburgh: University of Pittsburgh, 1963) 22.

[8] Kurt Koffka, *Principles of Gestalt psychology* (New York: Harcourt, Brace & World, Inc., 1936), 176.

the 1950s overthrown behaviorism as the dominant approach. The dominance of cognitive science continues to date. The dissatisfaction with the claims of behaviorism and the arrival of computers were the primary catalyst for the cognitive revolution. The appearance of the digital computer allowed cognitive scientists to describe human behavior in terms of the encoding, storage, retrieval, and manipulation of information.

Scholars and researchers of various fields like philosophy, psychology, sociology, artificial intelligence, linguistics, and neuroscience realized that understanding the mechanism of the mind would require an interdisciplinary approach towards the study of mind and cognition. This interdisciplinary mindset paved the way for the conception of cognitive science in the 1960s. Cognitive sciences, which began as an intellectual movement in the 1950s, took a cognitive revolution. The meteoric rise of digital computers during the 1950s supported the emergence of cognitive science and revolutionized the understanding of the mind.[9] The new vocabulary of the information processing system and digital computers became an analogy to explain the functioning of the mind. The advent and progress of computers helped develop a new computational and representational vocabulary to understand the mind. Many philosophers, psychologists, scholars in artificial intelligence were mesmerized by the information processing model of computers. Computers became a vital metaphor to understand the mind paving the way for computation and representation-based understanding.

Newell and Simon presented an extensive theory of problem solving following the information processing model.[10] Their book *Human Problem Solving* became a bedrock for the later cognitive research in problem solving and established the information-theoretic models as superior to other problem-solving models.

Simon summarizes the connection among the three above mentioned components along with their relation to information processing theory as,

> Information theory have made especially good progress in providing explanation of the processes for solving relatively well-structured puzzles, like problems of the sorts that have been most commonly studied in the psychological laboratories. The theories describe the behaviour as an interaction between an *information processing system*, the problem solver, and *the task environment*, the latter representing the task as described by the experimenter. In approaching the task, the problem solver represents the situation in terms of a *problem space*, which is a way of viewing the task environment.[11]

---

[9] See George A. Miller, "The cognitive revolution: a historical perspective," *Trends in cognitive sciences* 7(3), 2003.

[10] See Newell and Simon, *Human Problem Solving.*

[11] Herbert A. Simon, "Information-processing theory of human problem solving," in William Estes (ed.), *Handbook of learning and cognitive processes* (NJ: Lawrence Erlbaum Associates, 1978), 272.

Three apparent components of the information processing system, task environment, and problem space make the framework of IPTPS (Figure 1). These components will also provide flesh to the bones of the theory. The following subsections elaborate on these components.

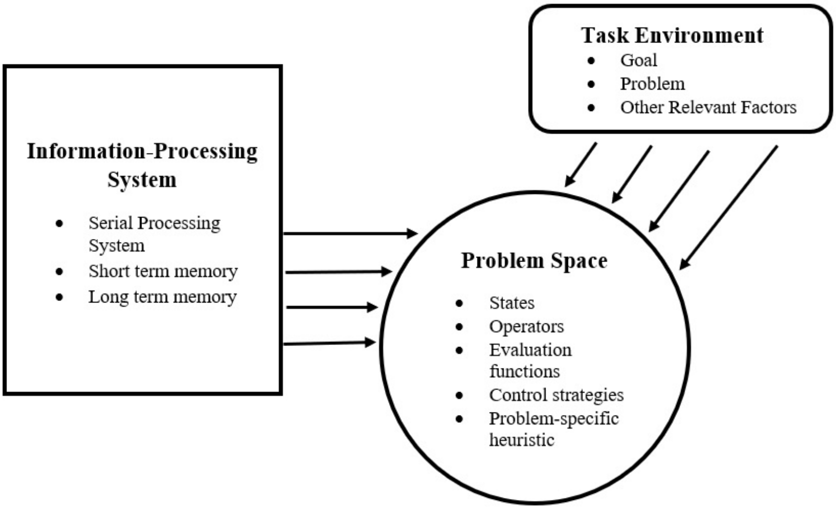

Figure 1. Components of Information-Processing Problem Solving Theory.

Characteristics of information processing systems mean broad underlying features of human neurophysiology, which supports IPTPS. The core traits of the human processing system are as follows.

1) The system is a serial processing system, i.e., one-process-at-a-time. It takes tens or hundreds of milliseconds to execute the elementary processes of the system.
2) Short-term memory, which has a capacity of few (between 4 to 7) symbols or chunks, holds the input and output of the process of the system. Immediate call experiments provide evidence for seven chunks of symbol capacity of short-term memory. Experiments for search lists and simple arithmetic computation supply evidence for the transfer of a symbol inside short term memory and out of short term memory in 200 milliseconds.
3) Long-term memory has essentially unlimited storage, which the information processing system can access. Rote memory experiments were useful in understanding the evidence that 5 or 10 seconds are usually needed to save in long-term memory.

The evidence for these characteristics comes from two sources- one from the study of human problem solving behavior itself, and other evidence of the system's basic properties come from the laboratory task and experiments. These characteristics emerging from a psychological experiment are not beyond doubt. However, the lack of surety of the basic characteristics stems from the system being an adaptive and dynamic system. The meaning of an adaptive system here is that the information processing system's characteristics also depend on the nature of the task environment.

For Simon and Newell, "Task environment is the omniscient observer's way of describing the actual problem out there."[12] They posited the concept of task environment to the abstraction of a given problem.[13] In general, task environment refers to the choices, actions, and outcome a given user has for the task or problem. Thus, a task environment acts as a separator of the main task for allowing the problem solver to perform relevant action.

The majority of data in problem solving comes from the study of highly structured tasks like theorem proving, puzzle-solving, equation solving, and logical proofs. We will stick with the example of one of the most studied Tower of Hanoi puzzle to elucidate the structure of the task environment (Figure 2).[14]

The problem consists of three pegs and a pyramid of wooden disks. The objective is to move the disks one by one at the end peg. There are the following allowed moves to obey for doing so:

1. At a time, only one disk can be moved.
2. In each move, one has to take the upper disc from one of the stacks and place it on another stack or on an empty peg.
3. The smaller disk cannot have a larger disk on top of them.

---

[12] Herbert Simon and Allen Newell, "Human problem solving: The state of the theory in 1970." *American Psychologist,* 26(2), 1971, 151.

[13] David Kirsh, "Problem Solving and Situated Cognition," in Philip Robbins & M. Aydede (eds.), *The Cambridge Handbook of Situated Cognition* (Cambridge: Cambridge University Press, 2009), 265.

[14] See Robert M Gagné and Ernest C. Smith, "A Study of the Effects of Verbalization on Problem Solving." *Journal of Experimental Psychology* 63 (1), 1962; Aiko Hormann, "Gaku: an artificial student," *Behavioral science* 10 (1), 1965; and Herbert A Simon, "The functional equivalence of problem solving skills," *Cognitive psychology* 7 (2), 1975.

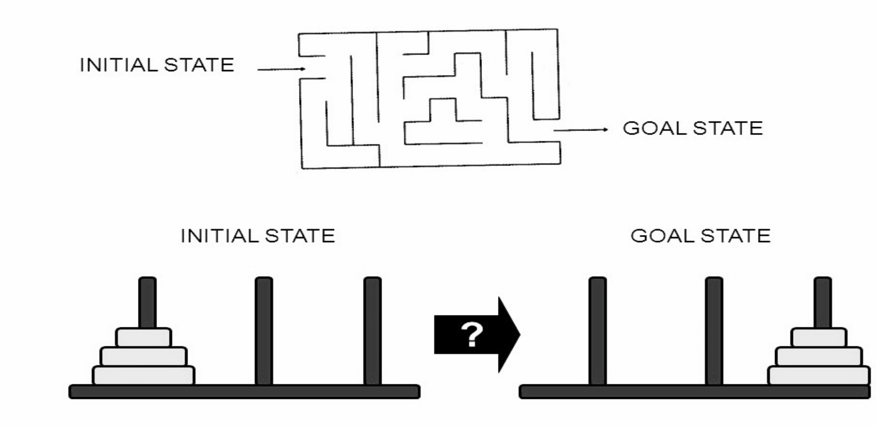

Figure 2. Tower of Hanoi puzzle.

There are different variations of the puzzle consisting of three two more disks. In this example, the description of the puzzle, and allowable moves, serve as a task environment. In order to solve the puzzle, the agent or subject needs to create a representation of the task in one's memory. When the problem solver represents the task environment, it becomes problem space. For arriving at the solution, the problem solver needs to search this problem space.

The representation created by the subject to solve a problem is known as problem space. It is closely related to the task environment but must be distinguished. An easy way to distinguish task environment and problem space is that task environment is a representation of the way an observer describes the problem, and in the problem space, problem solver represents the problem in the way he/she understands to chalk out a plan to solve it.[15]

The problem space is also understood as consisting of nodes that legal moves can create. Figure 3 depicts the problem space of the Tower of Hanoi puzzle. Here node means a state of knowledge. Furthermore, the state of knowledge is information available to a problem solver. Thus, problem-solving is nothing but a search in the problem space. Simon beautifully states, "the search for a solution is an odyssey through the problem space from one knowledge state to another until the current knowledge state includes the problem solution."[16] Thus, the Odyssey of human problem solving is not based on trial and error but on different strategies or heuristics.

[15] Simon, "Information-processing theory of human problem solving", 275.
[16] Simon, "Information-processing theory of human problem solving", 278.

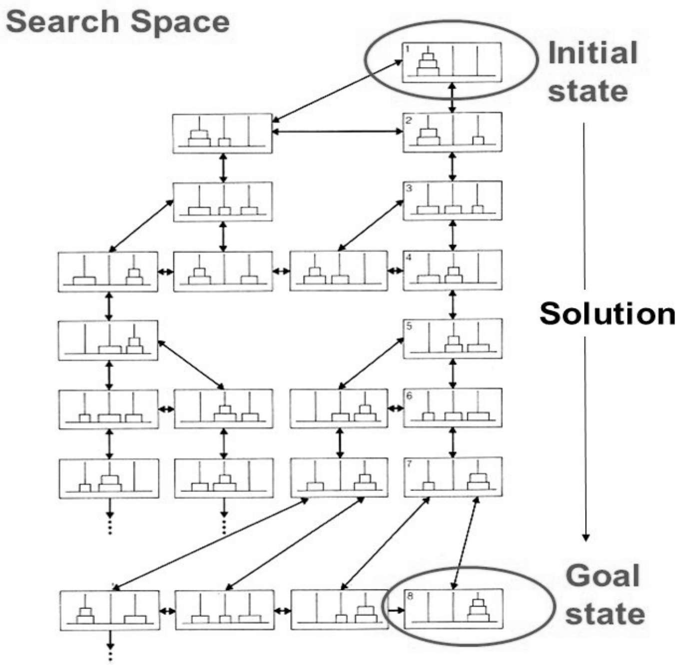

Figure 3. Problem space of Tower of Hanoi puzzle.

Problems arising in cooking, writing, engineering, design, politics, moral decisions, creating work, and other problems from real-life situations may not have a single unambiguous right answer. Some of the significant objections to the theory of information-processing theory of problem solving are as follows.

1. IPTPS considers search in the problem space to be central to human problem solving. But one can start the search in the problem space only after framing of the problem is taken care of. How people proceed to frame the problem is not fully explained by the information-processing theory of problem solving. No account is provided about how people generate representations in problem space from the instruction of task environment.
2. There is another issue of registration along with framing, which has been untouched by supporters of IPTPS. Registration connects the abstract problem space with the features of the real world while solving a real-world problem. In solving ill-defined problems, people often consult their problem space,

then connect in with the real world, and go back to problem space, according to the demands of the problem. There is a lot of interaction going on when people solve problems in a natural setting instead of a white-room environment. The nature of agent-environment relation is also not appropriately explored.

3. In order to solve their real-life problems, people surround themselves with resources. Cultural products-computers, mobile, whiteboards, and other people all become useful when confronted with real-life problems. These resources provide scaffolds to our understanding of the surrounding environment. With this understanding, people proceed to frame, register, and solving the problems. How we use surrounding resources and scaffolds is also unaddressed by the information theory of problem solving.

Eric Bredo pointed two important limitation of Newell and Simos's "symbol processing" model as,

1. Its omission of the continuing, dynamic interplay of person and environment in which problem-solving is a process of trying out ideas in practice, and not merely logically, in mind, "problems" being viewed as having their origin in person-environment interactions that do not proceed satisfactorily or cause doubt.[17]
2. Its omission of the social aspects of mind and the environment, such that problems are often divided up in a changing social division of labor and allocated to different parties, etc.[18]

Keeping these objections in mind, the next section presents an alternative way of conceptualizing human problem solving.

3. Affordance-Situation-Attunement Framework

In the last two decades, there has been a new development for understanding the process of the mind apart from the dominant representational-computational understanding of the mind. The new trend is to conceptualize the mind and cognition not only limited to the brain but as an emerging, dynamic concept arising out of the interaction of an agent with the surrounding environment. The trend is often affiliated with *embodied, embedded, extended, enactive* (4E), *distributed* cognition

[17] Eric Bredo (personal communication, August, 15, 2018)
[18] Eric Bredo (personal communication, August, 15, 2018)

forms.[19] Some scholars consider thesis related to embodiment and embedding under the umbrella of situated cognition.[20] There are also scholars who treat this new way of looking at cognition separately.[21] According to Robbins and Aydede , "Each of these theses contributes to a picture of mental activity as dependent on the situation or context in which it occurs, whether situation or context is relatively local or relatively global."[22] For instance: Embodied cognition maintain the role of the body in the emergence of cognition; embedded cognition argues for exploits of the natural and social environment in cognitive activities; extended cognition tries to extend the boundaries of cognition beyond individual organism (see figure 4).

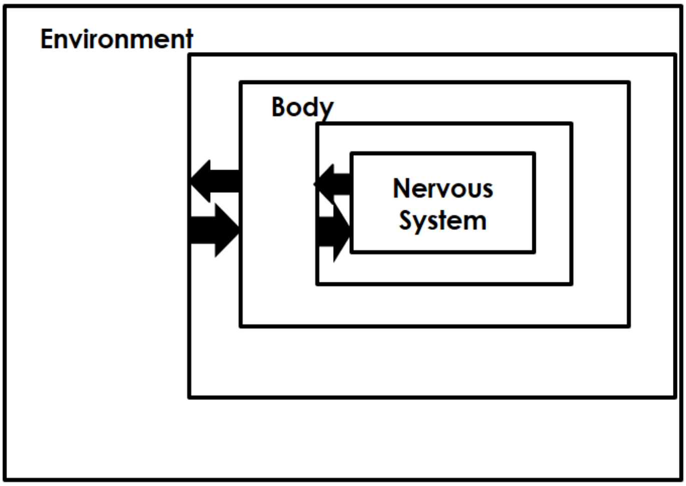

Figure 4. Situated Cognition as a Dynamic Interaction between brain, body, and environment

[19] See Anthony Chemero, *Radical embodied cognitive science* (Cambridge, MA: MIT Press, 2009); Andy Clark and David Chalmers, "The extended mind." *analysis* 58 (1), 1998; Shaun Gallagher, "Philosophical Antecedents of Situated Cognition.," in M Robbins & P. ; Aydede (eds.) *Cambridge Handbook of Situated Cognition. Cambridge* (Cambridge: Cambridge University Press, 2009); Daniel Hutto and Erik Myin, *Evolving Enactivism : Basic Minds Meet Content* (Cambridge, MA: MIT Press, 2017); and Margaret Wilson, "Six Views of Embodied Cognition." *Psychonomic Bulletin & Review* 9(4), 2002.

[20] See Philip Robbins, and Aydede Murat. "A Short Premier on Situated Cognition." in Philip Robbins & M. Aydede (eds.), *The Cambridge Handbook of Situated Cognition* (Cambridge: Cambridge University Press, 2009).

[21] See Michael Anderson, "Embodied Cognition: A Field Guide." *Artificial Intelligence* 149 (1), 2003; William Clancey, *Situated cognition: On human knowledge and computer representations* (Cambridge: Cambridge university press, 1997); and Robert A. Wilson, *Boundaries of the mind: The individual in the fragile sciences-Cognition* (Cambridge: Cambridge University Press, 2004).

[22] Robbins and Murat. "A Short Premier on Situated Cognition," 13.

A situated-ecological approach can address the interactivity in human problem solving. From an ecological and situated point of view, problems are not an abstraction having a formal structure that remains the same in all situations. Problems are understood as taking place in a concrete situation and are solved in context-specific ways by using social, material, or cultural resources. With these additions, the *problem* is seen as changing due to the response of the physical and social environment to one's actions. Cognitive research in problem solving conceptualizes problem solving as necessarily having a start state and goal state. However, in the paper, for the ecological perspective, we have considered the use and meaning of the word *problem* in an extended Deweyan sense as, "...the meaning of word problem to whatever–no matter how slight or commonplace in character–perplexes and challenges the mind…a state of hesitation, perplexity, or doubt"[23], and problem solving as an emergent behavior as a consequence of the interaction between active human agents and an affordance-rich environment. I would unpack this claim in the rest of the section. The ecological perspective is also a situated perspective, because both share the emphasis on the agent and environment interaction. With these additions, the *problem* is seen as changing due to the response of the physical and social environment to one's actions.

An ecological perspective on problem solving shares a similar concern for the neglect of situated aspect of problem solving. Clark proposed the Principle of Ecological Assembly (PEA) to capture agent and environment dynamic in solving problems.

> According to the PEA, the canny cognizer tends to recruit, on the spot, whatever mix of problem-solving resources will yield an acceptable result with a minimum of effort. It is important that, according to the PEA, the recruitment process marks no special distinction among neural, bodily, and environmental resources except insofar as these somehow affect the total effort involved.[24]

Reiterating the ecological nature of human problem solving, Shapiro also considers human problem solving as an ecological matter.[25] An organism uses the problem-relevant resource and offerings present in the environment to solve its problems. The organism also uses the environment to offload and simplify complex abstract tasks by utilizing the perception-action loop. Organisms continuously search

[23] John Dewey, *How we think* (New York: Dover Publications, 1910/1997), 9.

[24] Andy Clark, *Supersizing the mind: Embodiment, action, and cognitive extension* (Oxford: Oxford University Press, 2008), 13.

[25] See Lawrence Shapiro, *Embodied cognition* (New York: Routledge, 2011).

the environment to seek the fit between problem requirements and environmental fit, leaving the irrelevant strategies in favor of the efficient ones. In order to capture the ecological aspect of human problem solving, the paper proposes a new affordance-based framework as Affordance-Situation-Attunement (ASA) (see figure 6). I will first discuss the three components in detail: first affordance, second situation, and final attunement.

Gibson coined the term affordances to address the complementarity of organism and environment.[26] He conceptualized affordances as dispositional properties. Dispositional properties are the properties belonging both to the environment and agent. These properties open the agents towards the possibilities of action as perceived affordances. In Gibson's own words,

> The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment.[27]

By suggesting offering in the environment, Gibson implied the presence of threats in the form of negative affordances and promises as positive affordances. Affordances are possibilities of action based on both the properties of the environment and the capacity of an agent.[28] Affordances are about the complementarity of the environment and organism. It is possible that different organisms would perceive different affordances of the same object. When an organism perceives affordance, it is not just the perception of physical properties but also physical objects. To clarify the action-orientated meaning of affordances, Gibson sometimes used *verb phrase-able*. For example, one can describe a chair as seat-able, doorknob as rotatable, fire as cook-with-able, tea as drink-able.

---

[26] See James J. Gibson, *The ecological approach to visual perception: classic edition* (New York: Psychology Press, 1979/2015).

[27] James J. Gibson, *The ecological approach to visual perception: classic edition*, 127.

[28] See Pankaj Singh, "The philosophy of affordances," *Philosophical Psychology* 33 (6), 2020.

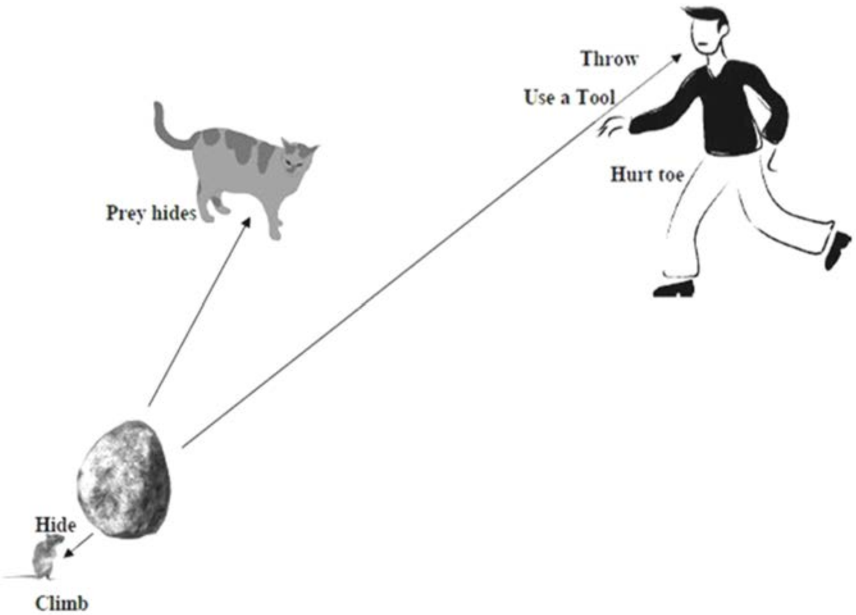

Figure 5. Based on their capacities, the different organisms may perceive different affordances of the same object. The same stone presents different affordance hence different possibilities of actions to a cat, rat, and human.

J. J. Gibson made another vital but claimed about affordances, "But, actually, an affordance is neither an objective property nor a subjective property; or it is both if you like."[29] Affordances can be considered in a way that a bearer possesses them, but at the same time, they are subjective because the perception of them is dependent upon the capacity and feature of the organism. In another way, affordances are objective because their existence is not subject to the act of perception. However, affordances are subjective as they are dependent upon the agent's action possibilities. For example, a chair provides support for a human but not for an elephant. Here, the supportability of the chair is an affordance for the human. In the examples, the affordance of the chair is objective because its existence is not dependent on human perception, but at the same time supportability of the chair for humans implies the subjective feature of the affordance. The difficulty of grasping the conceptual unity of objective-subjective dualism stems from discreetly viewing the environment and organism. Affordances are ways to highlight the

[29] James J. Gibson, *The ecological approach to visual perception: classic edition*, 129.

complementarity and inseparability of organisms and the environment. Scarantino emphasized, "the affordance property is possessed by a bearer relative to a specific organism or class of organisms."[30] As shown in figure 5, in terms of the possibility of action, the affordance of the same stone is perceived differently by the human, cat, and rat. Thowability, graspability, or hidebility is not some extra entity in the world, but the method of making sense of complimentarily of the shape of stone and features and capacity of other involved organisms.

The next element is *situation*. Interaction is also a critical element for the continuity of experience. From the very beginning of his writings, Dewey emphasized the role of interaction between humans as biological agents and the environment surrounding them.[31] Thus, Dewey viewed human cognition not as a passive activity in an individual's isolated mind but as an interactive activity between biological beings situated in a social environment. Human cognition and experience become an emergent phenomenon due to the interactional and transactional relationship between organisms, their physical and social environment. Dewey advocated a situated human experience "In actual experience, there is never any such isolated singular object or event; an object or event is always a special part, phase, or aspect, of an environing experienced world - a *situation.*"[32]

Continuous and mutual interaction between organism and environment is the basis for experiences in different situations. For Dewey, this interaction between organism and environment is taken together for a situation.[33] Thus, to Dewey, living in a world means continuous interaction between individuals, objects, and other persons, giving rise to different situations. The human experience is the outcome of such interactions in different situations. He further emphasized the inseparability of situation and interaction.[34]

An experience becomes a transactional relationship between individuals and their environment. The environment consists of everything that is part of the concerned situation, objects, people, events, topics. So, for Dewey, the environment is a set of conditions that give rise to human experience.[35] These conditions may include one's desires, capabilities, need, purpose, challenges, problems, and so on so forth. The situation is a dynamic concept in which it changes according to an individual's interaction with the environment.

---

30 Andrea Scarantino, "Affordances explained." *Philosophy of science* 70 (5), 2003, 955.
31 See John Dewey, "The new psychology," *Andover Review* 2, 1884.
32 John Dewey. *Logic: the theory of inquiry* (New York: Holt, Rinehart & Winston, 1938a) 67, emphasis added.
33 See John Dewey, *Experience and education* (New York: Macmillan, 1938b), 42.
34 John Dewey, *Experience and education* (New York: Macmillan, 1938b), 33.
35 Ibid., 44.

Change in the world does not mean one starts living in a different world but means that different aspects of the world have now become the organism's environment. Change in the environment further presents the organism in different situations. An individual keeps on increasing one's knowledge and skills in order to deal with different situations. The continual experience of individual takes the form of inquiry which help the organism in solving their problems. Continuous, situated pragmatic intervention makes human problem solving a matter of rearranging the environment and behavior, physical resources, tools, and socio-cultural relations.[36]

The final element in the framework is attunement. Attunement is an interactive concept; it requires embodied interaction with the environment to make the person familiar with her surrounding affordances. Humans, as situated-embodied agents, pick up and discover the information and affordances overflowing in their environment through the need, interests, constraints, demands of the particular situation. The attunement of an individual to her environment bolsters the perception of the information and affordances in a given situation about the critical nature of attunement to information. About the critical nature of attunement to information and affordances, J. J. Gibson argued,

> The state of a perceptual system is altered when it is attuned to information of a certain sort. The system has become sensitized. Differences are noticed that were previously not noticed. Features become distinctive that were formerly vague.[37]

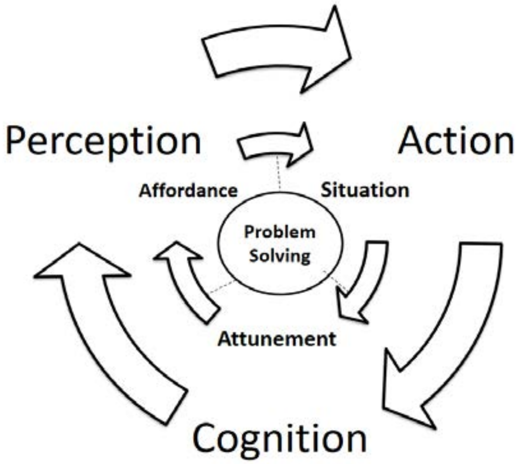

Figure 6. *Situatedness of interactive problem solving*

---

36 See Shaun Gallagher. "Pragmatic interventions into enactive and extended conceptions of cognition." *Philosophical Issues* 24 (1), 2014.

37 James J. Gibson, "*The ecological approach to visual perception: classic edition*", 254.

The increased attunement of an agent to the environment makes her/him sensitive in distinguishing situations; provides feedback to own performance; develops a loop of attunement and problem solving activities. Any environment offers a multitude of affordances. Given the concern at hand for the agent, some offerings of the affordances would not be relevant, and some would be relevant for problem solving action.

After getting acquainted with the ASA framework elements, it is time to discuss the overall impact of these elements on the conception of human problem solving. The cognitive perspective primarily uses two conceptual tools of schemata and procedure to explain the so-called higher cognitive processes like reading, pattern recognition, decision making, and problem solving. Schemata and procedures are linked with the concept of representation. In information-theoretic explanation for higher cognitive activities, including IPTPS approach to problem solving, is more to do with processing and manipulating symbolic representations. The descriptions of problem solving behavior are driven by the hypotheses about the representation, symbol manipulations, and computation.

The paper argues that schemata and procedures are not the only way to cognize problem solving. The complementarity of affordances, situation, and attunements for shaping an affordance-based framework of human problem solving can address the interactivity in human problem solving behavior.

Situations have been discussed in the literature of situational theory as relations. They are equally productive notions for ecological analysis. *If-then relations* are a formal way to represent constraints in various situations.[38] The section discussed affordances as mutual, emergent, and relational properties of the embodied and situated interaction between agent and environment. Such a notion of affordances opens the possibility for an individual to participate in problem solving activities. Combined with the *if-then* idea of a situation with the possibility of action provided by affordances and attunement, it offers a reliable conceptual alternative to understand the mechanism of human problem solving.

In the affordance-situation-attunement (ASA) analysis, the antecedent is affordances of the tools, structure, and resources present in the environment; the consequent is the activity, which is possible due to the properties of the environment and capacity of a person. In ASA, attunement implies an organism's ability to be attuned to the affordances, constraints, invariants, and cues present in the environment.

[38] See Jon Barwise, *Constraints, Channels and the Flow of Information,* (Stanford, CA: Center for the Study of Language and Information, 1993); Jon Barwise and John Perry, *Situations and attitudes* (Cambridge, MA: MIT Press, 1983); and Keith Devlin, *Logic and Information* (Cambridge: Cambridge University Press, 1995).

ASA supports an interactionist account of problem solving, in which structures in the environment and abilities of an embodied agent both are at the core of making sense of perception and cognition. Problem solving skills of an active agent are dependent on the attunement to a situation, and constraints of the environment, to which the agent is attuned. Attunement presents the affordances of the environment for possibilities of action. An agent picks up the relevant affordances with her perceptual system to proceed with the problem in hand. The action of the agent sometimes leads to the co-construction of the environment. During the activity of solving a problem, an agent tries to see things differently to come up with a way to solve the problem. In her attempt to see something differently, the agent registers the affordances in the environment. New affordances might lead to the construction of some new task-relevant structures in the environment. The new structures could serve as a scaffold or resource for further solution-related affordances. By embodied, situated exploration of registration, projection, and attunement of the affordances, agents solve the problem using the affordances pertinent to the situation.

It would be beneficial to consider some differences between problem space account of IPTPS and affordances-based ASA. There are two main differences.

1. IPTPS is limited to the search in a problem space. In contrast, ASA of problem solving is about the evaluation of the perceived affordances. Attunement bypasses the need for the construction of internal representation for the possible action. Humans explore choice points rather than internally generating them. Coming across choice points is linked with actions performed by an embodied and situated agent.
2. The second difference regards the mechanism of the transfer of problem solving skills. In IPTPS, the transfer of problem solving skills or expertise is a matter of detecting deep structural similarities in the problem and then mapping over the successful method from the source domain to the target domain. By contrast, in ASA, the transfer of expertise is concerned with detecting the situation-specific affordance and getting attuned to it.

The conception of affordances ASA pursues makes it publicly available and discoverable by an active, embodied, and situated agent who has the appropriate capacity to solve the problem. An agent equipped with relevant abilities picks up affordances of useable resources available in her environment.[39] These picked-up affordances offer the agent the possibilities of framing, registering, and solving the problem.

---

[39] See Edward S Reed, *Encountering the world: Toward an ecological psychology* (Oxford University Press, 1996); and Anthony Chemero, *Radical embodied cognitive science.*

The criticism raised against the information-theoretic account for failing to account for framing, registration, and interactivity can be raised against affordance-based problem solving. A detractor of the affordance account of problem solving might ask how the agent discovers relevant affordances in a particular situation? This question is linked with another issue of the relationship between an embodied agent and affordance. Or simply put, the nature of agent environment interaction while solving a problem? ASA analysis addresses these objections. ASA also provides the solution to framing, registration, and interaction problems at once by making the perception of task-relevant affordances available to her for a problem solving action. The starting point is to understand the nature of problems people solve in a concrete real-world setting. The problems humans solve are not knowledge-lean, as it is the case with game and puzzle cognition. Humans bring more expertise to generally knowledge-rich problems encountered in their daily activities.[40] As a situated-embodied agent, humans pick up and discover the affordances overflowing in their environment through the need, interests, constraints, demands of the particular situation. They need not always mentally generate a problem space based on representation to solve an encountered problem. The attunement of an individual to her environment bolsters the perception of the affordances in a given situation.

The increased attunement of an agent to her environment makes her sensitive in distinguishing situations; provides feedback to her own performance; develops a loop of attunement and problem solving activities. The more an agent is attuned to an environment, the better the chances of singling our relevant affordances; the more an agent solves problems, the more attuned she becomes to the specific environment. In this way, the agent unreflectively solves a problem by adequate attunement to the demands of the concrete situation. Any environment offers a multitude of affordances. Given the concern at hand for the agent, some offerings of the affordance would not be relevant, and some would be relevant for problem solving action.

The solicitation of affordance is dependent on one's concerns in a dynamic interactive environment.[41] The inviting property of affordances promotes an agent

[40] See Hubert L. Dreyfus, "Intelligence without representation–Merleau-Ponty's critique of mental representation The relevance of phenomenology to scientific explanation." *Phenomenology and the cognitive sciences* 1 (4), 2002; Evan Thompson, *Mind in life: Biology, phenomenology, and the sciences of mind* (Cambridge, MA: The Belknap Press of Harvard University Press, 2010); and Francisco J. Varela, Evan Thompson, and Eleanor Rosch, *The embodied mind: Cognitive science and human experience* (Cambridge: MIT press, 1991/2016).

[41] See Eric Rietveld, "Context-switching and responsiveness to real relevance," in J. Kiverstein & M. Wheeler (eds.), *Heidegger and cognitive science: New directions in cognitive science and philosophy (*Basingstoke, Hampshire, UK: Palgrave Macmillan, 2012); and Erik Rietveld, and Julian Kiverstein. "A rich landscape of affordances." *Ecological psychology* 26 (4), 2014.

in navigating a concrete problematic situation. The solicitation hinges on the dynamic interaction between the agent's abilities and the constraints present in the environment. For the problem solving activity, engagement with relevant affordances is specific to the concerned situation.

The failure of IPTPS to address the ill-defined problems in their framework is related to the nature of ill-defined problems being dynamic. Dynamicity in ill-defined problems indicates an activity-based agent-environment interaction in real-world problems. From an ecological perspective, human problem solving processes are dynamic. The dynamics of environmental information are of special interest to us. In our analysis, the problem solver also plays a crucial role along with the perceiving-acting cycle for progression towards the goal. The unfolding of the perception-action cycle towards a goal much (may?) not be understood as linear or unitary.

In our approach, goal is not a unitary point, but the possibilities of multiple responses to a problem. So, the framework of ecological psychology is a better fit to address the mechanism of ill-defined problems. It is often the case with real-life human problems that they dynamically reveal subproblems in moving towards the overall problem. Thus, humans pursue a set of nested goals. In contrast with IPTPS, ASA's description of problem solving relies on dynamics, which is a better way to capture the continuous coupled interaction between a problem solver and environment.

I am not the first one to bring the insights of ecological psychology to human problem solving. The work of Rasmussen and Vicente stands out in this regard due to their successful implementation of concepts of ecological psychology to complex work domains. Rasmussen proposed a *skills, rules, knowledge* (SRK) framework to help the designers combine the aspects of human cognition with the requirements of information in a system.[42] Rasmussen came up with another framework, abstract hierarchy (AH), for modeling complex socio-technical work environments.[43] Building on SRK and AH frameworks, Rasmussen and Vicente laid the foundation for the framework of ecological interface design (EID).[44] They incorporated the insights from the ecological psychology of human perception to

[42] See Jens Rasmussen, "Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models." *IEEE transactions on systems, man, and cybernetics,* 3, 1983.

[43] See Jens Rasmussen, "The role of hierarchical knowledge representation in decision-making and system management." *IEEE Transactions on systems, man, and cybernetics,* 2, 1985.

[44] See Jens Rasmussen and Kim J. Vicente. "Coping with human errors through system design: implications for ecological interface design." *international Journal of Man-machine Studies,* 31(5), 1989.

apply it to real-world environments rather than laboratory environments.[45] The primary aim of EID is to support the knowledge workers in adapting to change and novelty.[46] Vicente has applied EID to different systems such as aircraft management, military, anesthesiology, and computer networks.[47]

Vicente developed another framework as cognitive work analysis (CWA) to provide a toolkit for developing different skills and strategies to model complex socio-technical work systems.[48] He proposed a synthesis between information processing theories, ecological psychology, and the distributed aspect of cognition. He advocated using external representations to distribute cognition for offloading demands of cognition.

Similarly, Greeno also tried to develop a dynamic, relational, ecological perspective of knowledge, problem solving, skilled performance, and learning by using the concept of affordance, constraints, and invariants.[49] His conception of *situativity* aims to synthesize behaviorism and information processing theories using the concepts of ecological psychology. He argued for the retention of information processing and representation as internal mediating variables. He envisioned merging behaviorist's emphasis on environmental activity with the cognitivist's reliance on symbol manipulation and information processing. Although I appreciate and agree with the goal and aim of different frameworks attempting to synthesize, however, we distance ourselves from such synthesis in favor of a nonrepresentational, radical commitment of ecological psychology.[50] Thus, the ASA is committed to a nonrepresentation approach to elaborate on the embodied, situated, and interactive nature of human problem solving.

---

[45] See Kim J. Vicente and Jens Rasmussen. "The ecology of human-machine systems II: Mediating 'direct perception' in complex work domains." *Ecological psychology* 2 (3), 1990; and Kim J. Vicente and Jens Rasmussen. "Ecological interface design: Theoretical foundations." *IEEE Transactions on systems, man, and cybernetics* 22 (4), 1992.

[46] See Kim J. Vicente, Klaus Christoffersen, and Alex Pereklita. "Supporting operator problem solving through ecological interface design." *IEEE transactions on systems, man, and cybernetics* 25 (4), 1995; and Kim J. Vicente. *Cognitive work analysis: Toward safe, productive, and healthy computer-based work* (New Jersey: Lawrence Erlbaum Associates, Inc., Publishers, 1999).

[47] See Kim J. Vicente, "Ecological interface design: Progress and challenges." *Human factors* 44 (1), 2002.

[48] See Kim J. Vicente, "The Human Factor: Revolutionizing the way people live with technology Routledge", (New York: Read Books Ltd, 2004).

[49] See James G. Greeno, "The situativity of knowing, learning, and research." *American psychologist* 53 (1), 1998.

[50] See Miguel Segundo-Ortin, Manuel Heras-Escribano, and Vicente Raja. "Ecological psychology is radical enough: a reply to radical enactivists." *Philosophical Psychology* 32, (7), 2019.

4. Conclusion

The paper attempted to present an alternative understanding of human problem solving. This attempt makes agent-environment interaction a unit of analysis instead of overemphasizing brain processes. Although the attempts to bring insights from ecological psychology to human problem solving are already in place, we want to appeal to use ecological concepts of information, affordance, action-perception cycle, and attunement to expand our understanding of problem solving. The sketched perspective has continuity with situated approaches to cognition. It focuses explicitly on the dynamics of agent-environment interaction from a nonrepresentational point of view. Computational-representational and information processing paradigm continue to be the dominant paradigm for the research in mind and cognition. Information processing theories are still the received view for the research in skilled actions. However, new research programs and trends in alternative ways of conceptualizing the mind also garner theoretical and experimental support from people working in the varied field of inquiry associated with mind, brain, environment, and cognition. Making problem solving a target of analysis, the paper made a case that information processing models are not "the only game in town."[51]

Affordances are a crucial element of ecological psychology, but there are many other associated concepts in ecological psychology, e.g., perception-action continuity, organism-environment system, ecological scale, ecological information, specificity, direct perception, that needs to be taken into account for developing a full-fledged ecological theory of human problem solving. Apart from using the conceptual treasure of ecological psychology, it would be equally decisive to be open to the insights present in young interdisciplinary research programs of E-cognition for a full-fledged ecological theory. In the paper, with the help from the concept of affordance, we tried to have a perspective on human problem solving. However, many questions are left for an ecological theory of problem solving to follow up and answer. When does an agent notices relevant affordances? And, provided a huge number of possible affordances, exactly which one will agent attends to? An ecological theory of problem solving must tell who, when, why some people can see the relevant affordance in invariance, and some others cannot? What is the control mechanism of the dynamical problem solving system using affordances? What is the reason that sometimes, despite attunement, affordances and constraints are visible sometimes not? The paper has briefly dealt with some

[51] Jerry Fodor *LOT 2: The language of thought revisited*. (Oxford: Oxford University Press, 2008), 113.

of these questions. These questions suggest more focus on ethnographic studies into concrete real-life problem solving, revealing different ecological aspects in solving problems. I would like to emphasize one more time that I do not label other approaches to problem solving–behaviorist, gestaltist, or information-theoretic as useless. They all have crucial insights into their respective framework. Through the concept of affordance, the paper has offered a new perspective on human problem solving, which could pave the way for the ecological theory of problem solving. Ecological theory of problem solving and other approaches of problem solving would be an important method to understand human problem solving holistically, bridging the gap between internal and external dichotomies. For such holistic understanding, more model building, ethnography and experimental research are required.

BIBLIOGRAPHY

Anderson, Michael, "Embodied Cognition: A Field Guide." In *Artificial Intelligence,* Volume 194, Issue 1, 2003, 91–130.

Barwise, John, *Constraints, Channels and the Flow of Information*, Stanford, CA: Center for the Study of Language and Information, 1993.

Barwise, Jon, and John Perry, Situations and attitudes, Cambridge, MA: MIT Press, 1983.

Chemero, Anthony, *Radical embodied cognitive science*, Cambridge, MA: MIT Press, 2009.

Clancey, William, *Situated cognition: On human knowledge and computer representations*, Cambridge: Cambridge University press, 1997.

Clark, Andy, and David Chalmers, "The extended mind," *analysis,* Volume 58, Issue 1, 1998, 7-19.

Devlin, Keith , *Logic and Information*, Cambridge : Cambridge University Press, 1995

Dewey, John. "The new psychology," *Andover Review,* Volume 2, 1884, 278-289.

Dewey, John, *How we think,* New York: Dover Publications, 1910/1997.

Dewey, John. *Logic: the theory of inquiry,* New York: Holt, Rinehart & Winston, 1938a.

Dewey, John, *Experience and education*, New York: Macmillan, 1938b.

Dreyfus, Hubert L. "Intelligence without representation–Merleau-Ponty's critique of mental representation The relevance of phenomenology to scientific explanation." *Phenomenology and the cognitive sciences,* Volume 1, Issue, 4, 2002, 367-383.

Dunbar, Kevin, "Problem solving," in William Bechtel, and George Graham (eds.), *A companion to cognitive science,* Oxford: Blackwell Publishing Ltd, 1998, 289-298.

Duncker, Karl, "On problem-solving.", trans Lynne S. Lees. *Psychological monographs,* Volume 58, Issue 5, 1945, i-113.

Fodor, Jerry A. *LOT 2: The language of thought revisited*. Oxford: Oxford University Press, 2008.

Gagné, Robert M and Ernest C. Smith, "A Study of the Effects of Verbalization on Problem Solving." *Journal of Experimental Psychology,* Volume 63, Issue 1, 1962, 12-18.

Gallagher, Shaun. "Philosophical Antecedents of Situated Cognition," in M Robbins & P. ; Aydede (eds.) *Cambridge Handbook of Situated Cognition. Cambridge*, Cambridge: Cambridge University Press, 2009, 35–51.

Gallagher, Shaun. "Pragmatic interventions into enactive and extended conceptions of cognition." *Philosophical Issues,* Volume 24, Issue 1, 2014, 110-126.

Greeno, James G. "The situativity of knowing, learning, and research." *American psychologist,* Volume 53, Issue 1, 1998, 5-26.

Hormann, Aiko, "Gaku: an artificial student," *Behavioral science,* Volume 10, Issue 1, 1965, 88-109

Hutto, Daniel D and Erik Myin, *Evolving Enactivism : Basic Minds Meet Content*, Cambridge, MA: MIT Press, 2017.

Koffka, Kurt, *Principles of Gestalt psychology*, New York: Harcourt, Brace & World, Inc., 2013.

Kirsh, David, "Problem Solving and Situated Cognition," in Philip Robbins & M. Aydede (eds.), *The Cambridge Handbook of Situated Cognition*, Cambridge: Cambridge University Press, 2009, 264–306.

Miller, George A, "The cognitive revolution: a historical perspective," *Trends in cognitive sciences,* Volume 7, Issue 3, 2003, 141-144.

Newell, Allen, and Herbert Alexander Simon, *Human problem solving,* Englewood Cliffs, NJ: Prentice-hall, 1972.

Popper, Karl, *All life is problem solving*, London: Routledge, 2013.

Rasmussen, Jens. "Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models." *IEEE transactions on systems, man, and cybernetics,* Volume 3, 1983, 257-266.

Rasmussen, Jens. "The role of hierarchical knowledge representation in decision-making and system management." *IEEE Transactions on systems, man, and cybernetics,* Volume 2, 1985, 234-243.

Rasmussen, Jens, and Kim J. Vicente. "Coping with human errors through system design: implications for ecological interface design." *international Journal of Man-machine Studies,* Volume 31, Issue 5, 1989, 517-534.

Reed, Edward S, *Encountering the world: Toward an ecological psychology*. Oxford University Press, 1996.

Rietveld, Eric, "Context-switching and responsiveness to real relevance," in J. Kiverstein & M. Wheeler (eds.), *Heidegger and cognitive science: New directions in cognitive science and philosophy,* Basingstoke, Hampshire, UK: Palgrave Macmillan, 2012, 105–135.

Rietveld, Erik, and Julian Kiverstein. "A rich landscape of affordances." *Ecological psychology,* Volume 26, Issue 4, 2014, 325-352.

Robertson, S. Ian, *Problem solving: Perspectives from cognition and neuroscience*, New York: Routledge, 2016.

Robbins, Philip, and Aydede Murat. "A Short Premier on Situated Cognition." in Philip Robbins & M. Aydede (eds.), *The Cambridge Handbook of Situated Cognition*, Cambridge: Cambridge University Press, 2009, 3–10.

Segundo-Ortin, Miguel, Manuel Heras-Escribano, and Vicente Raja. "Ecological psychology is radical enough: a reply to radical enactivists." *Philosophical Psychology,* Volume 32, Issue 7, 2019, 1001-1023.

Sellars, Wilfrid, "Philosophy and the scientific image of man," in Robert G. Colodny (ed.), *cience, perception and reality,* Pittsburgh: University of Pittsburgh, 1963, 1–40.

Simon, Herbert A, "The functional equivalence of problem solving skills," *Cognitive psychology,* Volume 7, Issue 2, 1975, 268-288.

Simon, Herbert A. "Information-processing theory of human problem solving," in William Estes (ed.), *Handbook of learning and cognitive processes,* Hillsdale, NJ: Lawrence Erlbaum Associates, 1978, 271-295.

Simon, Herbert A., and Allen Newell, "Human problem solving: The state of the theory in 1970." *American Psychologist,* Volume 26, Issue 2, 1971, 145–159.

Wilson, Margaret, "Six Views of Embodied Cognition." *Psychonomic Bulletin & Review,* Volume 9, Issue 4, 2002, 625–36.

Wilson, Robert A. *Boundaries of the mind: The individual in the fragile sciences-Cognition*, Cambridge: Cambridge University Press, 2004.

Clark, Andy, *Supersizing the mind: Embodiment, action, and cognitive extension*, Oxford: Oxford University Press, 2008.

Shapiro, Lawrence, *Embodied cognition*, New York: Routledge, 2011.

Gibson, James J, *The ecological approach to visual perception: classic edition*, New York: Psychology Press, 1979/2015.

Singh, Pankaj. "The philosophy of affordances," *Philosophical Psychology,* Volume 33, Issue 6, 2020, 888-892.

Scarantino, Andrea, "Affordances explained." *Philosophy of science,* Volume 70, Issue 5, 2003, 949-961.

Thompson, Evan, *Mind in life: Biology, phenomenology, and the sciences of mind.* Cambridge, MA: The Belknap Press of Harvard University Press, 2010.

Varela, Francisco J., Evan Thompson, and Eleanor Rosch, *The embodied mind: Cognitive science and human experience*. Cambridge: MIT press, 1991/2016.

Vicente, Kim J., and Jens Rasmussen. "The ecology of human-machine systems II: Mediating 'direct perception' in complex work domains." *Ecological psychology,* Volume 2, Issue 3, 1990, 207-249.

Vicente, Kim J., and Jens Rasmussen. "Ecological interface design: Theoretical foundations." *IEEE Transactions on systems, man, and cybernetics,* Volume 22, Issue 4, 1992, 589-606.

Vicente, Kim J., Klaus Christoffersen, and Alex Pereklita. "Supporting operator problem solving through ecological interface design." *IEEE transactions on systems, man, and cybernetics,* Volume 25, Issue 4, 1995, 529-545.

Vicente, Kim J. *Cognitive work analysis: Toward safe, productive, and healthy computer-based work*. New Jersey: Lawrence Erlbaum Associates, Inc., Publishers, 1999.

Vicente, Kim J. "Ecological interface design: Progress and challenges." *Human factors,* Volume 44, Issue 1, 2002, 62-78.

Vicente, Kim J. "The Human Factor: Revolutionizing the way people live with technology Routledge", New York: Read Books Ltd, 2004.