Cognition: How the Mind Solves Problems

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Thinking or Thought Process refers to ideas or arrangements of ideas that are the result of the process of thinking. Though thinking is an activity considered essential to humanity, there is no consensus as to how we define or understand it.

Because thought underlies many human actions and interactions, understanding its physical and metaphysical origins, processes, and effects has been a longstanding goal of many academic disciplines including linguistics, psychology, neuroscience, philosophy, artificial intelligence, biology, sociology and cognitive science.

Thinking allows humans to make sense of, interpret, represent or model the world they experience, and to make predictions about that world. It is therefore helpful to an organism with needs, objectives, and desires as it makes plans or otherwise attempts to accomplish those goals.

The word thought comes from Old English þoht, or geþoht, from stem of þencan "to conceive of in the mind, consider".

The word "thought" may mean:

a single product of thinking or a single idea ("My first thought was 'no.'")
the product of mental activity ("Mathematics is a large body of thought.")
the act or system of thinking ("I was frazzled from too much thought.")
the capacity to think, reason, imagine, and so on ("All her thought was applied to her work.")
the consideration of or reflection on an idea ("The thought of death terrifies me.")
recollection or contemplation ("I thought about my childhood.")
half-formed or imperfect intention ("I had some thought of going.")
anticipation or expectation ("She had no thought of seeing him again.")
consideration, attention, care, or regard ("He took no thought of his appearance" and "I did it without thinking.")
judgment, opinion, or belief ("According to his thought, honesty is the best policy.")
the ideas characteristic of a particular place, class, or time ("Greek thought")
the state of being conscious of something ("It made me think of my grandmother.")
tending to believe in something, especially with less than full confidence ("I think that it will rain, but I am not sure.")

Definitions may or may not require that thought:

take place within a human brain (see anthropomorphism),
take place as part of a living biological system (see Alan Turing and Computing Machinery and Intelligence),
take place only at a conscious level of awareness (see Unconscious Thought Theory),
require language,

is principally or even only conceptual, abstract ("formal"),
involve other concepts such as drawing analogies, interpreting, evaluating, imagining, planning, and remembering.

Definitions of thought may also be derived directly or indirectly from theories of thought.

Theories

"Outline of a theory of thought-processes and thinking machines" (Caianiello) - thought processes and mental phenomena modeled by sets of mathematical equations
Surfaces and Essences: Analogy as the Fuel and Fire of Thinking (Hofstadter and Sander) - a theory built on analogies
The Neural Theory of Language and Thought (Feldman and Lakoff) - neural modeling of language and spatial relations
ThoughtForms - The Structure, Power, and Limitations of Thought (Baum) - a theory built on mental models
Unconscious Thought Theory - thought that is not conscious
Linguistics theories - The Stuff of Thought (Steven Pinker, Noam Chomsky) - The linguistic and cognitive theory that thought is based on syntactic and linguistic recursion processes

Philosophy

What is most thought-provoking in these thought-provoking times, is that we are still not thinking.

--?Martin Heidegger

The phenomenology movement in philosophy saw a radical change in the way in which we understand thought. Martin Heidegger's phenomenological analyses of the existential structure of man in Being and Time cast new light on the issue of thinking, unsettling traditional cognitive or rational interpretations of man which affect the way we understand thought. The notion of the fundamental role of non-cognitive understanding in rendering possible thematic consciousness informed the discussion surrounding Artificial Intelligence during the 1970s and 1980s.

Phenomenology, however, is not the only approach to thinking in modern Western philosophy. Philosophy of mind is a branch of philosophy that studies the nature of the mind, mental events, mental functions, mental properties, consciousness and their relationship to the physical body, particularly the brain. The mind-body problem, i.e. the relationship of the mind to the body, is commonly seen as the central issue in philosophy of mind, although there are other issues concerning the nature of the mind that do not involve its relation to the physical body.

The mind-body problem

The mind-body problem concerns the explanation of the relationship that exists between minds, or mental processes, and bodily states or processes. The main aim of philosophers working in this area is to determine the nature of the mind and mental states/processes, and how--or even if--minds are affected by and can affect the body.

Human perceptual experiences depend on stimuli which arrive at one's various sensory organs from the external world and these stimuli cause changes in one's mental state, ultimately causing one to feel a sensation, which may be pleasant or unpleasant. Someone's desire for a slice of pizza, for example, will tend to cause that person to move his or her body in a specific manner and in a specific direction to obtain what he or she wants. The question, then, is how it can be possible for conscious experiences to arise out of a lump of gray matter endowed with nothing but electrochemical properties. A related problem is to explain how someone's propositional attitudes (e.g. beliefs and desires) can cause that individual's neurons to fire and his muscles to contract in exactly the correct manner. These comprise some of the puzzles that have confronted epistemologists and philosophers of mind from at least the time of René Descartes.

Functionalism vs. embodiment

The above reflects a classical, functional description of how we work as cognitive, thinking systems. However the apparently irresolvable mind-body problem is said to be overcome, and bypassed, by the embodied cognition approach, with its roots in the work of Heidegger, Piaget, Vygotsky, Merleau-Ponty and the pragmatist John Dewey.

This approach states that the classical approach of separating the mind and analysing its processes is misguided: instead, we should see that the mind, actions of an embodied agent, and the environment it perceives and envisions, are all parts of a whole which determine each other. Therefore, functional analysis of the mind alone will always leave us with the mind-body problem which cannot be solved.

Biology

A neuron (also known as a neurone or nerve cell) is an excitable cell in the nervous system that processes and transmits information by electrochemical signaling. Neurons are the core components of the brain, the vertebrate spinal cord, the invertebrate ventral nerve cord, and the peripheral nerves. A number of specialized types of neurons exist: sensory neurons respond to touch, sound, light and numerous other stimuli affecting cells of the sensory organs that then send signals to the spinal cord and brain. Motor neurons receive signals from the brain and spinal cord and cause muscle contractions and affect glands. Interneurons connect neurons to other neurons within the brain and spinal cord. Neurons respond to stimuli, and communicate the presence of stimuli to the central nervous system, which processes that information and sends responses to

other parts of the body for action. Neurons do not go through mitosis, and usually cannot be replaced after being destroyed, although astrocytes have been observed to turn into neurons as they are sometimes pluripotent.

Psychology

Psychologists have concentrated on thinking as an intellectual exertion aimed at finding an answer to a question or the solution of a practical problem. Cognitive psychology is a branch of psychology that investigates internal mental processes such as problem solving, memory, and language. The school of thought arising from this approach is known as cognitivism which is interested in how people mentally represent information processing. It had its foundations in the Gestalt psychology of Max Wertheimer, Wolfgang Köhler, and Kurt Koffka, and in the work of Jean Piaget, who provided a theory of stages/phases that describe children's cognitive development.

Cognitive psychologists use psychophysical and experimental approaches to understand, diagnose, and solve problems, concerning themselves with the mental processes which mediate between stimulus and response. They study various aspects of thinking, including the psychology of reasoning, and how people make decisions and choices, solve problems, as well as engage in creative discovery and imaginative thought. Cognitive theory contends that solutions to problems take the form of algorithms--rules that are not necessarily understood but promise a solution, or heuristics--rules that are understood but that do not always guarantee solutions. Cognitive science differs from cognitive psychology in that algorithms that are intended to simulate human behavior are implemented or implementable on a computer. In other instances, solutions may be found through insight, a sudden awareness of relationships.

In developmental psychology, Jean Piaget was a pioneer in the study of the development of thought from birth to maturity. In his theory of cognitive development, thought is based on actions on the environment. That is, Piaget suggests that the environment is understood through assimilations of objects in the available schemes of action and these accommodate to the objects to the extent that the available schemes fall short of the demands. As a result of this interplay between assimilation and accommodation, thought develops through a sequence of stages that differ qualitatively from each other in mode of representation and complexity of inference and understanding. That is, thought evolves from being based on perceptions and actions at the sensorimotor stage in the first two years of life to internal representations in early childhood. Subsequently, representations are gradually organized into logical structures which first operate on the concrete properties of the reality, in the stage of concrete operations, and then operate on abstract principles that organize concrete properties, in the stage of formal operations. In recent years, the Piagetian conception of thought was integrated with information processing conceptions. Thus, thought is considered as the result of mechanisms that are responsible for the representation and processing of information. In this conception, speed of processing, cognitive

control, and working memory are the main functions underlying thought. In the neo-Piagetian theories of cognitive development, the development of thought is considered to come from increasing speed of processing, enhanced cognitive control, and increasing working memory.

Positive psychology emphasizes the positive aspects of human psychology as equally important as the focus on mood disorders and other negative symptoms. In Character Strengths and Virtues, Peterson and Seligman list a series of positive characteristics. One person is not expected to have every strength, nor are they meant to fully capsulate that characteristic entirely. The list encourages positive thought that builds on a person's strengths, rather than how to "fix" their "symptoms".

Psychoanalysis

"Id", "ego", and "super-ego" are the three parts of the "psychic apparatus" defined in Sigmund Freud's structural model of the psyche; they are the three theoretical constructs in terms of whose activity and interaction mental life is described. According to this model, the uncoordinated instinctual trends are the "id"; the organized realistic part of the psyche is the "ego," and the critical and moralizing function the "super-ego."

The unconscious was considered by Freud throughout the evolution of his psychoanalytic theory a sentient force of will influenced by human desire and yet operating well below the perceptual conscious mind. For Freud, the unconscious is the storehouse of instinctual desires, needs, and psychic drives. While past thoughts and reminiscences may be concealed from immediate consciousness, they direct the thoughts and feelings of the individual from the realm of the unconscious.

For psychoanalysis, the unconscious does not include all that is not conscious, rather only what is actively repressed from conscious thought or what the person is averse to knowing consciously. In a sense this view places the self in relationship to their unconscious as an adversary, warring with itself to keep what is unconscious hidden. If a person feels pain, all he can think of is alleviating the pain. Any of his desires, to get rid of pain or enjoy something, command the mind what to do. For Freud, the unconscious was a repository for socially unacceptable ideas, wishes or desires, traumatic memories, and painful emotions put out of mind by the mechanism of psychological repression. However, the contents did not necessarily have to be solely negative. In the psychoanalytic view, the unconscious is a force that can only be recognized by its effects--it expresses itself in the symptom.

Sociology

Social psychology is the study of how people and groups interact. Scholars in this interdisciplinary

area are typically either psychologists or sociologists, though all social psychologists employ both the individual and the group as their units of analysis.

Despite their similarity, psychological and sociological researchers tend to differ in their goals, approaches, methods, and terminology. They also favor separate academic journals and professional societies. The greatest period of collaboration between sociologists and psychologists was during the years immediately following World War II. Although there has been increasing isolation and specialization in recent years, some degree of overlap and influence remains between the two disciplines.

The collective unconscious, sometimes known as collective subconscious, is a term of analytical psychology, coined by Carl Jung. It is a part of the unconscious mind, shared by a society, a people, or all humanity, in an interconnected system that is the product of all common experiences and contains such concepts as science, religion, and morality. While Freud did not distinguish between an "individual psychology" and a "collective psychology," Jung distinguished the collective unconscious from the personal subconscious particular to each human being. The collective unconscious is also known as "a reservoir of the experiences of our species."

In the "Definitions" chapter of Jung's seminal work Psychological Types, under the definition of "collective" Jung references representations collectives, a term coined by Lucien Lévy-Bruhl in his 1910 book How Natives Think. Jung says this is what he describes as the collective unconscious. Freud, on the other hand, did not accept the idea of a collective unconscious.

Problem Solving

Problem solving consists of using generic or ad hoc methods, in an orderly manner, for finding solutions to problems. Some of the problem-solving techniques developed and used in artificial intelligence, computer science, engineering, mathematics, or medicine are related to mental problem-solving techniques studied in psychology.

Definition

The term problem solving is used in many disciplines, sometimes with different perspectives, and often with different terminologies. For instance, it is a mental process in psychology and a computerized process in computer science. Problems can also be classified into two different types (ill-defined and well-defined) from which appropriate solutions are to be made. Ill-defined problems are those that do not have clear goals, solution paths, or expected solution. Well-defined problems have specific goals, clearly defined solution paths, and clear expected solutions. These problems also allow for more initial planning than ill-defined problems. Being able to solve problems sometimes involves dealing with pragmatics (logic) and semantics (interpretation of the problem).

The ability to understand what the goal of the problem is and what rules could be applied represent the key to solving the problem. Sometimes the problem requires some abstract thinking and coming up with a creative solution.

Psychology

Thomas J. D'Zurilla in 1988 defined problem solving as a "cognitive-affective-behavioral process through which an individual (or group) attempts to identify, discover, or invent effective means of coping with problems encountered in every day living". It is an evolutionary drive for living organisms and an important coping skill for dealing with a variety of concerns. Problem solving specifically in psychology refers to a state of desire for reaching a definite 'goal' from a present condition that either is not directly moving toward the goal, is far from it, or needs more complex logic for finding a missing description of conditions or steps toward the goal. In each case "where you want to be" is an imagined (or written) state in which you would like to be and the solutions are situation- or context-specific. This process includes problem finding or 'problem analysis', problem shaping, generating alternative strategies, implementation and verification of the selected solution. Distinguished feature of a problem is that there is a goal to be reached and how you get there depends upon problem orientation (problem-solving coping style and skills) and systematic analysis. The nature of human problem solving processes and methods is a field of study and work for mental health professionals. Methods of studying problem solving include introspection, behaviorism, simulation, computer modeling, and experiment. Social psychologists look into the person-environment relationship aspect of the problem and independent and interdependent problem-solving methods. Problem solving has been defined as a higher-order cognitive process and intellectual function that requires the modulation and control of more routine or fundamental skills.

Problem solving has two major domains: mathematical problem solving and personal problem solving both are seen in terms of some difficulty or barrier is encountered. Empirical researches show that self-interest and interpersonal skills; collaborative and instrumental problem approach (it helps in reflective and expansive understanding of the problem situation and its preferable outcome); strategy fluency (the number and diversity of strategies) and conceptual clarity that can lead to an action-identification (Vallacher & Wegner, 1987); temporal lifespan perspective that lead to selectivity in strategy (problem focused and emotion focused strategies); self-efficacy and problem familiarity; formation of 'carry over' relationships (egalitarian friendship, romantic ties, cliques, hygge's, etc.) that helps individuals mutually move through life and provide a sense of identity (Antonucci, Birditt, & Ajrouch, 2011); negotiation; type of relationships (obligatory vs. voluntary); gender typing; problem focused and emotion focused strategies as some strategies and factors that influence everyday problem solving. Neuropsychologists have studied that individuals with frontal lobe injuries with deficits in emotional control and reasoning can be remediated with effective rehabilitation and could improve the capacity of injured persons to resolve everyday

problems (Rath, Simon, Langenbahn, Sherr, & Diller, 2003).

Interpersonal everyday problem solving is dependent upon the individual personal motivational and contextual components. One such component is the emotional valence of "real-world" problems and it can either impede or aid problem-solving performance. Researchers have focused on the role of emotions in problem solving (D'Zurilla & Goldfried, 1971; D'Zurilla & Nezu, 1982), demonstrating that poor emotional control can disrupt focus on the target task and impede problem resolution and likely lead to negative outcomes such as fatigue, depression, and inertia (Rath, Langenbahn, Simon, Sherr, & Diller, 2004). In conceptualization, human problem solving consists of two related processes: problem orientation, the motivational/attitudinal/affective approach to problematic situations and problem-solving skills. Studies conclude people's strategies cohere with their goals (Hoppmann & Blanchard-Fields, 2010, Berg et al., 1998) and they are stemmed from the natural process of comparing oneself with others (Sonstegard and Bitter, 1998).

Cognitive sciences

The early experimental work of the Gestaltists in Germany placed the beginning of problem solving study (e.g., Karl Duncker in 1935 with his book The psychology of productive thinking). Later this experimental work continued through the 1960s and early 1970s with research conducted on relatively simple (but novel for participants) laboratory tasks of problem solving. Choosing simple novel tasks was based on the clearly defined optimal solutions and their short time for solving, which made it possible for the researchers to trace participants' steps in problem-solving process. Researchers' underlying assumption was that simple tasks such as the Tower of Hanoi correspond to the main properties of "real world" problems and thus the characteristic cognitive processes within participants' attempts to solve simple problems are the same for "real world" problems too; simple problems were used for reasons of convenience and with the expectation that thought generalizations to more complex problems would become possible. Perhaps the best-known and most impressive example of this line of research is the work by Allen Newell and Herbert A. Simon. Other experts have shown that the principle of decomposition improves the ability of the problem solver to make good judgment.

Computer science and algorithmics

In computer science and in the part of artificial intelligence that deals with algorithms ("algorithmics"), problem solving encompasses a number of techniques known as algorithms, heuristics, root cause analysis, etc. In these disciplines, problem solving is part of a larger process that encompasses problem determination, de-duplication, analysis, diagnosis, repair, etc.

Engineering

Problem solving is used in when products or processes fail, so corrective action can be taken to prevent further failures. It can also be applied to a product or process prior to an actual fail event, i.e., when a potential problem can be predicted and analyzed, and mitigation applied so the problem never actually occurs. Techniques such as Failure Mode Effects Analysis can be used to proactively reduce the likelihood of problems occurring.

Military science

In military science, problem solving is linked to the concept of "end-states", the desired condition or situation that strategists wish to generate.:xiii, E-2 The ability to solve problems is important at any military rank, but is highly critical at the command and control level, where it is strictly correlated to the deep understanding of qualitative and quantitative scenarios. Effectiveness of problem solving is "a criterion used to assess changes in system behavior, capability, or operational environment that is tied to measuring the attainment of an end state, achievement of an objective, or creation of an effect". Planning for problem-solving is a "process that determines and describes how to employ 'means' in specific 'ways' to achieve 'ends' (the problem's solution)."

Other

Forensic engineering is an important technique of failure analysis that involves tracing product defects and flaws. Corrective action can then be taken to prevent further failures.
Reverse engineering attempts to discover the original problem-solving logic used in developing a product by taking it apart.
Other problem solving tools are linear and nonlinear programming, queuing systems, and simulation.

Problem-solving strategies

Problem-solving strategies are the steps that one would use to find the problem(s) that are in the way to getting to one's own goal. Firend's problem solving model (PSM) is practical in application and incorporates the conventional 5WH approach, with a systematic process of investigation, implementation and assessment cycle. Some would refer to this as the "problem-solving cycle" (Bransford & Stein, 1993). In this cycle one will recognize the problem, define the problem, develop a strategy to fix the problem, organize the knowledge of the problem cycle, figure out the resources at the user's disposal, monitor one's progress, and evaluate the solution for accuracy. The reason it is called a cycle is that once one is completed with a problem another usually will pop up.

Blanchard-Fields (2007) looks at problem solving from one of two facets. The first looking at those problems that only have one solution (like mathematical problems, or fact-based questions) which are grounded in psychometric intelligence. The other that is socioemotional in nature and are

unpredictable with answers that are constantly changing (like what's your favorite color or what you should get someone for Christmas).

The following techniques are usually called problem-solving strategies'

Abstraction: solving the problem in a model of the system before applying it to the real system
Analogy: using a solution that solves an analogous problem
Brainstorming: (especially among groups of people) suggesting a large number of solutions or ideas and combining and developing them until an optimum solution is found
Divide and conquer: breaking down a large, complex problem into smaller, solvable problems
Hypothesis testing: assuming a possible explanation to the problem and trying to prove (or, in some contexts, disprove) the assumption
Lateral thinking: approaching solutions indirectly and creatively
Means-ends analysis: choosing an action at each step to move closer to the goal
Method of focal objects: synthesizing seemingly non-matching characteristics of different objects into something new
Morphological analysis: assessing the output and interactions of an entire system
Proof: try to prove that the problem cannot be solved. The point where the proof fails will be the starting point for solving it
Reduction: transforming the problem into another problem for which solutions exist
Research: employing existing ideas or adapting existing solutions to similar problems
Root cause analysis: identifying the cause of a problem
Trial-and-error: testing possible solutions until the right one is found

Problem-solving methods

Eight Disciplines Problem Solving
GROW model
How to Solve It
OODA loop (observe, orient, decide, and act)
PDCA (plan-do-check-act)
Root cause analysis
RPR problem diagnosis (rapid problem resolution)
TRIZ (in Russian: Teoriya Resheniya Izobretatelskikh Zadach, "theory of solving inventor's problems")
A3 problem solving
System dynamics
Hive mind

Common barriers to problem solving

Common barriers to problem solving are mental constructs that impede our ability to correctly solve problems. These barriers prevent people from solving problems in the most efficient manner possible. Five of the most common processes and factors that researchers have identified as barriers to problem solving are confirmation bias, mental set, functional fixedness, unnecessary constraints, and irrelevant information.

Confirmation bias

Within the field of science there exists a set of fundamental standards, the scientific method, which outlines the process of discovering facts or truths about the world through unbiased consideration of all pertinent information and through impartial observation of and/or experimentation with that information. According to this method, one is able to most accurately find a solution to a perceived problem by performing the aforementioned steps. The scientific method does not prescribe a process that is limited to scientists, but rather one that all people can practice in their respective fields of work as well as in their personal lives. Confirmation bias can be described as one's unconscious or unintentional corruption of the scientific method. Thus when one demonstrates confirmation bias, one is formally or informally collecting data and then subsequently observing and experimenting with that data in such a way that favors a preconceived notion that may or may not have motivation. Research has found that professionals within scientific fields of study also experience confirmation bias. Andreas Hergovich, Reinhard Schott, and Christoph Burger's experiment conducted online, for instance, suggested that professionals within the field of psychological research are likely to view scientific studies that are congruent with their preconceived understandings more favorably than studies that are incongruent with their established beliefs.

Motivation refers to one's desire to defend or find substantiation for beliefs (e.g., religious beliefs) that are important to one. According to Raymond Nickerson, one can see the consequences of confirmation bias in real-life situations, which range in severity from inefficient government policies to genocide. With respect to the latter and most severe ramification of this cognitive barrier, Nickerson argued that those involved in committing genocide of persons accused of witchcraft, an atrocity that occurred from the 15th to 17th centuries, demonstrated confirmation bias with motivation. Researcher Michael Allen found evidence for confirmation bias with motivation in school children who worked to manipulate their science experiments in such a way that would produce their hoped for results. However, confirmation bias does not necessarily require motivation. In 1960, Peter Cathcart Wason conducted an experiment in which participants first viewed three numbers and then created a hypothesis that proposed a rule that could have been used to create that triplet of numbers. When testing their hypotheses, participants tended to only create additional triplets of numbers that would confirm their hypotheses, and tended not to create triplets that would negate or disprove their hypotheses. Thus research also shows that people can and do work to confirm theories or ideas that do not support or engage personally significant

beliefs.

Mental set

Mental set was first articulated by Abraham Luchins in the 1940s and demonstrated in his well-known water jug experiments. In these experiments, participants were asked to fill one jug with a specific amount of water using only other jugs (typically three) with different maximum capacities as tools. After Luchins gave his participants a set of water jug problems that could all be solved by employing a single technique, he would then give them a problem that could either be solved using that same technique or a novel and simpler method. Luchins discovered that his participants tended to use the same technique that they had become accustomed to despite the possibility of using a simpler alternative. Thus mental set describes one's inclination to attempt to solve problems in such a way that has proved successful in previous experiences. However, as Luchins' work revealed, such methods for finding a solution that have worked in the past may not be adequate or optimal for certain new but similar problems. Therefore, it is often necessary for people to move beyond their mental sets in order to find solutions. This was again demonstrated in Norman Maier's 1931 experiment, which challenged participants to solve a problem by using a household object (pliers) in an unconventional manner. Maier observed that participants were often unable to view the object in a way that strayed from its typical use, a phenomenon regarded as a particular form of mental set (more specifically known as functional fixedness, which is the topic of the following section). When people cling rigidly to their mental sets, they are said to be experiencing fixation, a seeming obsession or preoccupation with attempted strategies that are repeatedly unsuccessful. In the late 1990s, researcher Jennifer Wiley worked to reveal that expertise can work to create a mental set in persons considered to be experts in certain fields, and she furthermore gained evidence that the mental set created by expertise could lead to the development of fixation.

Functional fixedness

Functional fixedness is a specific form of mental set and fixation, which was alluded to earlier in the Maier experiment, and furthermore it is another way in which cognitive bias can be seen throughout daily life. Tim German and Clark Barrett describe this barrier as the fixed design of an object hindering the individual's ability to see it serving other functions. In more technical terms, these researchers explained that "ubjects become "fixed" on the design function of the objects, and problem solving suffers relative to control conditions in which the object's function is not demonstrated." Functional fixedness is defined as only having that primary function of the object itself hinder the ability of it serving another purpose other than its original function. In research that highlighted the primary reasons that young children are immune to functional fixedness, it was stated that "functional fixedness...subjects are hindered in reaching the solution to a problem by

their knowledge of an object's conventional function." Furthermore, it is important to note that functional fixedness can be easily expressed in commonplace situations. For instance, imagine the following situation: a man sees a bug on the floor that he wants to kill, but the only thing in his hand at the moment is a can of air freshener. If the man starts looking around for something in the house to kill the bug with instead of realizing that the can of air freshener could in fact be used not only as having its main function as to freshen the air, he is said to be experiencing functional fixedness. The man's knowledge of the can being served as purely an air freshener hindered his ability to realize that it too could have been used to serve another purpose, which in this instance was as an instrument to kill the bug. Functional fixedness can happen on multiple occasions and can cause us to have certain cognitive biases. If we only see an object as serving one primary focus than we fail to realize that the object can be used in various ways other than its intended purpose. This can in turn cause many issues with regards to problem solving. Common sense seems to be a plausible answer to functional fixedness. One could make this argument because it seems rather simple to consider possible alternative uses for an object. Perhaps using common sense to solve this issue could be the most accurate answer within this context. With the previous stated example, it seems as if it would make perfect sense to use the can of air freshener to kill the bug rather than to search for something else to serve that function but, as research shows, this is often not the case.

Functional fixedness limits the ability for people to solve problems accurately by causing one to have a very narrow way of thinking. Functional fixedness can be seen in other types of learning behaviors as well. For instance, research has discovered the presence of functional fixedness in many educational instances. Researchers Furio, Calatayud, Baracenas, and Padilla stated that "... functional fixedness may be found in learning concepts as well as in solving chemistry problems." There was more emphasis on this function being seen in this type of subject and others.

There are several hypotheses in regards to how functional fixedness relates to problem solving. There are also many ways in which a person can run into problems while thinking of a particular object with having this function. If there is one way in which a person usually thinks of something rather than multiple ways then this can lead to a constraint in how the person thinks of that particular object. This can be seen as narrow minded thinking, which is defined as a way in which one is not able to see or accept certain ideas in a particular context. Functional fixedness is very closely related to this as previously mentioned. This can be done intentionally and or unintentionally, but for the most part it seems as if this process to problem solving is done in an unintentional way.

Functional fixedness can affect problem solvers in at least two particular ways. The first is with regards to time, as functional fixedness causes people to use more time than necessary to solve any given problem. Secondly, functional fixedness often causes solvers to make more attempts to solve a problem than they would have made if they were not experiencing this cognitive barrier. In

the worst case, functional fixedness can completely prevent a person from realizing a solution to a problem. Functional fixedness is a commonplace occurrence, which affects the lives of many people.

Unnecessary constraints

Unnecessary constraints are another very common barrier that people face while attempting to problem-solve. This particular phenomenon occurs when the subject, trying to solve the problem subconsciously, places boundaries on the task at hand, which in turn forces him or her to strain to be more innovative in their thinking. The solver hits a barrier when they become fixated on only one way to solve their problem, and it becomes increasingly difficult to see anything but the method they have chosen. Typically, the solver experiences this when attempting to use a method they have already experienced success from, and they can not help but try to make it work in the present circumstances as well, even if they see that it is counterproductive.

Groupthink, or taking on the mindset of the rest of the group members, can also act as an unnecessary constraint while trying to solve problems. This is due to the fact that with everybody thinking the same thing, stopping on the same conclusions, and inhibiting themselves to think beyond this. This is very common, but the most well-known example of this barrier making itself present is in the famous example of the dot problem. In this example, there are nine dots lying in a square- three dots across, and three dots running up and down. The solver is then asked to draw no more than four lines, without lifting their pen or pencil from the paper. This series of lines should connect all of the dots on the paper. Then, what typically happens is the subject creates an assumption in their mind that they must connect the dots without letting his or her pen or pencil go outside of the square of dots. Standardized procedures like this can often bring mentally invented constraints of this kind, and researchers have found a 0% correct solution rate in the time allotted for the task to be completed. The imposed constraint inhibits the solver to think beyond the bounds of the dots. It is from this phenomenon that the expression "think outside the box" is derived.

This problem can be quickly solved with a dawning of realization, or insight. A few minutes of struggling over a problem can bring these sudden insights, where the solver quickly sees the solution clearly. Problems such as this are most typically solved via insight and can be very difficult for the subject depending on either how they have structured the problem in their minds, how they draw on their past experiences, and how much they juggle this information in their working memories In the case of the nine-dot example, the solver has already been structured incorrectly in their minds because of the constraint that they have placed upon the solution. In addition to this, people experience struggles when they try to compare the problem to their prior knowledge, and they think they must keep their lines within the dots and not go beyond. They do this because trying to envision the dots connected outside of the basic square puts a strain on their working memory.

Luckily, the solution to the problem becomes obvious as insight occurs following incremental movements made toward the solution. These tiny movements happen without the solver knowing. Then when the insight is realized fully, the "aha" moment happens for the subject. These moments of insight can take a long while to manifest or not so long at other times, but the way that the solution is arrived at after toiling over these barriers stays the same.

Irrelevant information

Irrelevant information is information presented within a problem that is unrelated or unimportant to the specific problem. Within the specific context of the problem, irrelevant information would serve no purpose in helping solve that particular problem. Often irrelevant information is detrimental to the problem solving process. It is a common barrier that many people have trouble getting through, especially if they are not aware of it. Irrelevant information makes solving otherwise relatively simple problems much harder.

For example: "Fifteen percent of the people in Topeka have unlisted telephone numbers. You select 200 names at random from the Topeka phone book. How many of these people have unlisted phone numbers?

The people that are not listed in the phone book would not be among the 200 names you selected. The individuals looking at this task would have naturally wanted to use the 15% given to them in the problem. They see that there is information present and they immediately think that it needs to be used. This of course is not true. These kinds of questions are often used to test students taking aptitude tests or cognitive evaluations. They aren't meant to be difficult but they are meant to require thinking that is not necessarily common. Irrelevant Information is commonly represented in math problems, word problems specifically, where numerical information is put for the purpose of challenging the individual.

One reason irrelevant information is so effective at keeping a person off topic and away from the relevant information, is in how it is represented. The way information is represented can make a vast difference in how difficult the problem is to be overcome. Whether a problem is represented visually, verbally, spatially, or mathematically, irrelevant information can have a profound effect on how long a problem takes to be solved; or if it's even possible. The Buddhist monk problem is a classic example of irrelevant information and how it can be represented in different ways:

A Buddhist monk begins at dawn one day walking up a mountain, reaches the top at sunset, meditates at the top for several days until one dawn when he begins to walk back to the foot of the mountain, which he reaches at sunset. Making no assumptions about his starting or stopping or about his pace during the trips, prove that there is a place on the path which he occupies at the same hour of the day on the two separate journeys.

This problem is near impossible to solve because of how the information is represented. Because it is written out in a way that represents the information verbally, it causes us to try and create a mental image of the paragraph. This is often very difficult to do especially with all the irrelevant information involved in the question. This example is made much easier to understand when the paragraph is represented visually. Now if the same problem was asked, but it was also accompanied by a corresponding graph, it would be far easier to answer this question; irrelevant information no longer serves as a road block. By representing the problem visually, there are no difficult words to understand or scenarios to imagine. The visual representation of this problem has removed the difficulty of solving it.

These types of representations are often used to make difficult problems easier. They can be used on tests as a strategy to remove Irrelevant Information, which is one of the most common forms of barriers when discussing the issues of problem solving. Identifying crucial information presented in a problem and then being able to correctly identify its usefulness is essential. Being aware of irrelevant information is the first step in overcoming this common barrier.

Cognitive sciences: two schools

In cognitive sciences, researchers' realization that problem-solving processes differ across knowledge domains and across levels of expertise (e.g. Sternberg, 1995) and that, consequently, findings obtained in the laboratory cannot necessarily generalize to problem-solving situations outside the laboratory, has led to an emphasis on real-world problem solving since the 1990s. This emphasis has been expressed quite differently in North America and Europe, however. Whereas North American research has typically concentrated on studying problem solving in separate, natural knowledge domains, much of the European research has focused on novel, complex problems, and has been performed with computerized scenarios (see Funke, 1991, for an overview).

Europe

In Europe, two main approaches have surfaced, one initiated by Donald Broadbent (1977; see Berry & Broadbent, 1995) in the United Kingdom and the other one by Dietrich Dörner (1975, 1985; see Dörner & Wearing, 1995) in Germany. The two approaches share an emphasis on relatively complex, semantically rich, computerized laboratory tasks, constructed to resemble real-life problems. The approaches differ somewhat in their theoretical goals and methodology, however. The tradition initiated by Broadbent emphasizes the distinction between cognitive problem-solving processes that operate under awareness versus outside of awareness, and typically employs mathematically well-defined computerized systems. The tradition initiated by Dörner, on the other hand, has an interest in the interplay of the cognitive, motivational, and social components of

problem solving, and utilizes very complex computerized scenarios that contain up to 2,000 highly interconnected variables (e.g., Dörner, Kreuzig, Reither & Stäudel's 1983 LOHHAUSEN project; Ringelband, Misiak & Kluwe, 1990). Buchner (1995) describes the two traditions in detail.

North America

In North America, initiated by the work of Herbert A. Simon on "learning by doing" in semantically rich domains (e.g. Anzai & Simon, 1979; Bhaskar & Simon, 1977), researchers began to investigate problem solving separately in different natural knowledge domains - such as physics, writing, or chess playing - thus relinquishing their attempts to extract a global theory of problem solving (e.g. Sternberg & Frensch, 1991). Instead, these researchers have frequently focused on the development of problem solving within a certain domain, that is on the development of expertise (e.g. Anderson, Boyle & Reiser, 1985; Chase & Simon, 1973; Chi, Feltovich & Glaser, 1981).

Areas that have attracted rather intensive attention in North America include:

Reading (Stanovich & Cunningham, 1991)
Writing (Bryson, Bereiter, Scardamalia & Joram, 1991)
Calculation (Sokol & McCloskey, 1991)
Political decision making (Voss, Wolfe, Lawrence & Engle, 1991)
Managerial problem solving (Wagner, 1991)
Lawyers' reasoning (Amsel, Langer & Loutzenhiser, 1991)
Mechanical problem solving (Hegarty, 1991)
Problem solving in electronics (Lesgold & Lajoie, 1991)
Computer skills (Kay, 1991)
Game playing (Frensch & Sternberg, 1991)
Personal problem solving (Heppner & Krauskopf, 1987)
Mathematical problem solving (Pólya, 1945; Schoenfeld, 1985)
Social problem solving (D'Zurilla & Goldfreid, 1971; D'Zurilla & Nezu, 1982)
Problem solving for innovations and inventions: TRIZ (Altshuller, 1994)

Characteristics of complex problems

As elucidated by Dietrich Dörner and later expanded upon by Joachim Funke, complex problems have some typical characteristics that can be summarized as follows:

Complexity (large numbers of items, interrelations and decisions)
enumerability
heterogeneity
connectivity (hierarchy relation, communication relation, allocation relation)

Dynamics (time considerations)
temporal constraints
temporal sensitivity
phase effects
dynamic unpredictability
Intransparency (lack of clarity of the situation)
commencement opacity
continuation opacity
Polytely (multiple goals)
inexpressiveness
opposition
transience

Collective problem solving

Problem solving is applied on many different levels – from the individual to the civilizational. Collective problem solving refers to problem solving performed collectively.

Social issues and global issues can typically only be solved collectively.

It has been noted that the complexity of contemporary problems has exceeded the cognitive capacity of any individual and requires different but complementary expertise and collective problem solving ability.

Collective intelligence is shared or group intelligence that emerges from the collaboration, collective efforts, and competition of many individuals.

In a 1962 research report, Douglas Engelbart linked collective intelligence to organizational effectiveness, and predicted that pro-actively 'augmenting human intellect' would yield a multiplier effect in group problem solving: "Three people working together in this augmented mode seem to be more than three times as effective in solving a complex problem as is one augmented person working alone".

Henry Jenkins, a key theorist of new media and media convergence draws on the theory that collective intelligence can be attributed to media convergence and participatory culture. He criticizes contemporary education for failing to incorporate online trends of collective problem solving into the classroom, stating "whereas a collective intelligence community encourages ownership of work as a group, schools grade individuals". Jenkins argues that interaction within a knowledge community builds vital skills for young people, and teamwork through collective intelligence communities contribute to the development of such skills.

Collective impact is the commitment of a group of actors from different sectors to a common

agenda for solving a specific social problem, using a structured form of collaboration.

After World War II the UN, the Bretton Woods organization and the WTO were created and collective problem solving on the international level crystallized since the 1980s around these 3 types of organizations. As these global institutions remain state-like or state-centric it has been called unsurprising that these continue state-like or state-centric approaches to collective problem-solving rather than alternative ones.

It has been observed that models of liberal democracy provide neither adequate designs for collective problem solving nor handling the substantive challenges in society such as crime, war, economic decline, illness and environmental degradation to produce satisfying outcomes.

Crowdsourcing is a process of accumulating the ideas, thoughts or information from many independent participants, with aim to find the best solution for a given challenge. Modern information technologies allow for massive number of subjects to be involved as well as systems of managing these suggestions that provide good results. With the Internet a new capacity for collective, including planetary-scale, problem solving was created.

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