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CLARK L. HULL'S COGNITIVE ARTICLES: A NEW PERSPECTIVE ON HIS BEHAVIOR SYSTEM*

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RESUMEN

Siguiendo los *Libros de Ideas* de Clark L. Hull y otros materiales de archivo, el artículo examina su evolución intelectual, desde la tesis doctoral sobre la formación de conceptos hasta el último borrador no publicado de un artículo sobre "inferencia concreta en el hombre". Clark Hull quiso especializarse en el estudio del razonamiento y, sin embargo, terminó siendo un teórico del aprendizaje, dejando inconclusa su obra cognitiva. En el artículo se analizan los factores principales de esta evolución.

ABSTRACT

Following Clark L. Hull's *Idea Books* and other archival materials, the paper tries to reconstruct Hull's intellectual evolution from its beginnings in the field of concept formation until his last manuscript, an unpublished draft on "Concrete Human Inference." Although Hull wanted to specialize in the psychology of reasoning, he became a theorist of learning and left his cognitive work unfinished. The main factors leading to this evolution are analyzed and evaluated.

Clark L. Hull's systematic theory of learning dominated American experimental psychology in the thirties and forties (Spence, 1952). Also relevant were his contributions to psychometrics and hypnosis, as exemplified by his books on *Aptitude Testing* (Hull, 1928b) and *Hypnosis and Suggestibility* (Hull 1933). Less influential have been his articles on

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* This paper is an abstract of a forthcoming book on Hull's Associative Mechanisms of Thinking to be published by Editorial Desclée de Brouwer, Bilbao.

cognition and human thought, especially after the advent of the "cognitive revolution" (Baars, 1986) and its criticisms to his Neobehavioristic system. However, for many years they were Hull's main intellectual pursuit, and certainly the part of his work he liked the most.

His doctoral dissertation on the "Quantitative Aspects of the Evolution of Concepts" (Hull, 1920) was the first study in the field made with a rigorous experimental methodology and without introspection. Together with other theoretical papers, such as "Knowledge and Purpose" (Hull, 1930), "Goal attraction and directing ideas" (Hull, 1931), "The concept of the habit-family hierarchy and maze learning" (Hull, 1934a), and "The mechanism of the assembly of behavior segments in novel combinations suitable for problem solution" (Hull, 1935), it was a part of a more ambitious project oriented to the explanation of higher thought processes.

Mainly to compensate for his bad memory, Hull wrote a series of notebooks - the *Idea Books* - with his original ideas concerning all sorts of psychological subjects. Covering a period of time which goes from October 1902 through April 1952, fragments of them were published by the late Robert B. Ammons (1920-1999) with the editing of Hull's former assistant and secretary Ruth Hays (Hull, 1962). These fragments, however, do not do justice to their contents (Triplett, 1982), which are much richer and give interesting hints on the development of his theories.

After reading all the manuscripts, one gets the impression that the theory of learning was neither Hull's final goal, nor the part of his work he liked the most. It was an important one, in the sense that it contributed to consolidating his leadership in American psychology, but it represented only an instrument for reaching the more general goal of delineating the associative mechanisms of thinking.

Since the very beginnings of his academic career, Hull's greatest ambition was to study the processes of abstraction, conception, and ultimately of reasoning. As he wrote on March 5, 1916, when his doctoral dissertation methodology was well under control:

> One thing seems pretty clear: I am not big enough a man naturally (by endowment) to achieve much in a broad field. Accordingly I must set myself a limited task and try by everything in my power to become the supreme authority in that phase of the science (...) *This subject shall be the psychology of abstraction and concept formation,* and perhaps, ultimately, of reasoning (Hull, 1962, p. 814).

A long time later, in March 1933, when the Yale academic authorities were pressing him to continue his psychometric work, Hull wrote: "This is all terribly depressing. If it is pursued restlessly, it is likely to thwart the

greatest ambition of my life, which has been to develop a systematic view to the higher mental powers supported by a vigorous series of experimental researches designed to test the hypotheses" (Hull, 1931-33, p. 234).

Three months later, when the crisis was over, he insisted: "I have always, since my undergraduate years of Ann Arbor, wished to specialize in the higher mental processes. The time seems to have arrived at which this may be realized in good measure" (Hull, 1933-34, p.5). But these wishes could not be accomplished because, a little later, he decided to concentrate his efforts on learning as a preliminary step to the explanation of the thought processes. After presenting the theory in *Principles of Behavior* (1943), he proceeded to its quantification, a difficult task that consumed his energies practically until the end of his days. After the final version of the postulates and theorems came out (Hull, 1951), he returned to his cognitive work, but on May 10, 1952, his sudden death put an end to his greatest ambition in life. Following the *Idea Books,* we will try to reconstruct in this paper the main stages in the process.

THE GENERALIZING ABSTRACTION

Clark L. Hull (1884-1952) was raised on a farm near Sickles, a small village in the State of Michigan. After finishing his elementary studies and teaching in a one-room rural school, he attended West Saginaw High School (1902-1903), and then continued his studies at the academy of Alma College, a small Presbyterian university. At the end of his second year, in 1905, an attack of typhoid fever, which was nearly fatal, left him with a generalized bad memory for names.

Once recovered from the illness, in 1906 Hull enrolled in Alma College as a freshman, and for two years he took courses in mathematics, physics, and chemistry in order to prepare for a career as a mining engineer. Once again, his plans were frustrated by illness. When he was 24 years old, he fell victim to an epidemic of poliomyelitis while working at the Oliver Iron Mines of Hibbing, Minnesota. Unable to work in the mine because of paralysis in one leg, he decided to become a psychologist, expecting that experimental psychology would give him the opportunity to design and work with automatic apparatus.

After a long convalescence, during which he read the *Principles of Psychology* (James, 1890), Hull entered the University of Michigan in the fall semester of 1911. The head of the department, Walter B. Pillsbury (1872-1960), had just published his *Psychology of reasoning* (1910), and this fact probably reawakened Hull's interest in thinking and reasoning.

The professor in charge of the laboratory, John P. Shepard (1881-1965), introduced him to the rigorous methodology of learning studies, and gave him a small Chinese-English dictionary containing the common ideographs and radicals that he used in his doctoral dissertation.

In 1913, Hull did some preliminary experiments on the formation of concepts with the students of the normal school at Richmond, Kentucky, where he was teaching. The following year, he started his graduate training at the Laboratory of Psychology of the University of Wisconsin, which was permeated by a practical atmosphere quite the opposite of the theoretical one at Michigan. The head of the department, Joseph Jastrow (1863-1944), introduced hypnosis research into the laboratory, and taught a medical course at the university's medical school, which he eventually turned over to Hull (Blumenthal, 1991). Hull gladly accepted it, and began his practice in the technique of hypnosis. At about the same time, he also taught the course on psychological tests and measurements, left by Daniel Starch (1883-1979), and worked very hard to develop a scientific basis for vocational guidance.

Hull continued his doctoral dissertation under the supervision of Vivian A.C. Henmon (1877-1950), director of the School of Education of Wisconsin. He developed a rigorous technique inspired in the Ebbinghaus experiments on memory in order to study the quantitative aspects of the generalizing abstraction (Gondra, 1989). With the Chinese characters of the dictionary Shepard had given him, he measured the efficacy of different methods of developing a kind of abstraction he referred to as "standard" because it was the most common in the concepts of daily life. The concept formation was not an end deliberately sought, but the means to attaining the goal of adjustment to the external conditions. Although it required the use of language, the process was quite unconscious. For instance, a child learns to name dogs with the word "dog" after unconsciously detecting a characteristic common to all dogs and not common to other animals such as cats or rabbits.

Under the influence of the applied atmosphere of Wisconsin, Hull emphasized the methodological aspects and objective measurements. But at the end of the thesis, he added a qualitative experiment, which called on subjects to draw the common radicals at different times. Their drawings indicated that the generalizing abstraction was a process of trial and error controlled by the laws of effect and exercise, as Edward L. Thorndike (1874-1949) had postulated in the second volume of his *Educational Psychology* (1913).

Thorndike's theory of analytical learning (Gondra, 1998), however, was not the main influence in the doctoral dissertation, as Hull himself recognized

by the end of 1915. Reflecting on the solution to a problem in the experimental technique, he remembered that "the a priori phase arose from the principle of James that the perception of similarity is the essence of reasoning power and probably of intelligence. This naturally led to the use of nonsense material containing a common element" (Hull, 1915-16, pp. 18-19).

In the *Principles*, James followed Alexander Bain in affirming that "*a native talent for perceiving analogies*" was "*the leading fact in genius*" (James, 1890/1950, I, p. 530). He explained it in the chapter on reasoning by relating similarity to "sagacity" or "perception of the essence". According to James, reasoning consisted in the extraction of the essential character that contained the key to the solution. The accumulation of data with this essential character, following the methods of J.S. Mill's *Logic* (1843), facilitated its discrimination and consequently its extraction. Since this accumulation was very easy for those gifted for association by similarity, he concluded:

> Our chief help toward noticing those special characters of phenomena, which, when once possessed and named, are used as reasons, class names, essences, or middle terms, *is this association by similarity*. Without it, indeed, the deliberate procedure of the scientific man would be impossible: he could never collect his analogous instances. But it operates of itself in highly-gifted minds without any deliberation, spontaneously connecting analogous instances, uniting in a moment what in nature the whole breadth of space and time keeps separate, and so permitting a perception of identical points in the midst of different circumstances, which mind governed wholly by the law of contiguity could never begin to attain (James, 1890/1950, II, p. 347).

Animals were unable to associate by similarity because they could not pay attention to abstract characters, and their associations were almost exclusively by contiguity.

This theory, which probably had some relationship to James' artistic sensibility (Leary, 1992), was the opposite of the mechanical one he proposed in the chapter on association of ideas. Then, the only causal law was contiguity, which appeared in three different forms: "impartial redintegration," "partial recall" and "association by similarity". The difference among them was only a quantitative one, depending on the number of nervous-tracts implied in the process. In "impartial redintegration" all the nerve paths of the outgoing thought were activated; in "partial recall" only the image selected by attention was active; and in "association by similarity" this portion was still smaller, corresponding to an abstract quality. James concluded by saying:

> To sum up, then, we see that *the difference among the three kinds of association reduces itself to a simple difference in the amount of that portion of the nerve-tract supporting the going thought which is operative in calling up the thought which comes.* But the *modus* operandi of this active part is the same, be it large or be it small (James, 1890/1950, I, p. 581).

Guided by these considerations, Hull prepared series of Chinese characters with the same common radical and asked the subjects to abstract it and associate it to the corresponding nonsense syllable. This radical was the common element that mediated in the transfer; such as it was shown in Thorndike's experiments (Thorndike, Woodworth, 1901). But in problem-solving and reasoning the situation was quite new and, consequently, had nothing in common with past experiences. Then, James recurred to a hypothetical nervous process which, by persisting more than the others, was the link connecting the different situations. The identical element was inside the organism, instead of being in the external world.

Following a similar kind of reasoning, Hull tried to explain the problem-solving behaviors by means of internal mechanisms belonging to the organism. But instead of postulating hypothetical nervous processes, as James did, he put the identical element in a series of internal stimuli and responses that mediated in the adjustments to environment.

TOWARD A NEOBEHAVIORISTIC PSYCHOLOGY

In February 1924, when the correlation machine was almost finished, Hull organized a theoretical seminar on reasoning. As he wrote in his "Seminar Notes in Psychology of Reasoning," his main goal was "to make a critical study of the more prominent theories of reasoning with the view to the isolation of problems which may be made the object of experimental attack" (Hull, 1924-26, p.1).

With this general purpose in mind, he planned to use the psychologies of reasoning by Pillsbury (1910) and Rignano (1923) as his main textbooks, but, in fact, centered almost exclusively on the later. Eugenio Rignano (1870-1930) was an Italian philosopher influenced by evolutionary thought, who placed great emphasis on biological drives in his explanation of reasoning (Sava, 1998). This fact, together with his vivid descriptions, greatly impressed Hull. But his subjectivism was incompatible with science, and for this reason he tried other sources of insight.

In January 1925, he instituted a seminar on Behaviorism aimed at "a critical constructive examination of the various behavioristic hypotheses"

(Hull, 1925, p. 2). The choosing of two such antagonistic textbooks as Watson's *Psychology* (1919) and Roback's *Behaviorism and Psychology (1923)* revealed an impartial attitude. Hull's main purpose was to try out the various explanations of the known facts in order to compare their adequacy. He would then proceed to formulate "stimulus-response" definitions of the mental processes. "In a sense," he wrote, "it will be an attempt to translate the older psychology into behavioristic terms, *in detail*, to see how will it work" (Hull, 1925, p. 2).

However, at the end of the seminar, Hull was quite decided on trying out a new theory of reasoning. As he wrote one year later with respect to the seminar on reasoning: "our problem is to work out a behavioristic theory of reasoning. From another point of view it is to meet the Gestalt contention that association never explains an inference. It is to work out the principles of association that lie at the basis of reasoning and inferences from a behavioristic standpoint" (Hull, 1924-26, p.76).

The above reference to Gestalt Theory is meaningful because it reveals its influence on Hull's acceptation of behaviorism. In his autobiographic account, he speaks of his interest in studying with Kurt Koffka (1886-1941) in Giessen. Having failed in his attempts to get a fellowship, he tried to bring Koffka to Wisconsin. When that took place, probably in January 1925, Koffka's negative expository approach made a very poor impression on him. According to Hull's testimony, Koffka spent most of time attacking Watson, and "while I found myself in general agreement with his criticisms of behaviorism, I came to the conclusion not that the Gestalt view was sound, but rather than Watson had not made out as clear a case for behaviorism as the facts warranted" (Hull, 1952a, p. 154).

Koffka's objections were the catalysts that set in motion Hull's approach to behavior theory, but probably more important was the impact of Köhler's *Mentality of Apes* (1917/1925). His experiments on "insight" revealed the inadequacies of Thorndike's theory of learning, because the chimpanzees' behaviors had a definite direction, unity and coherence that were lacking in the trial and error responses of the cats in the puzzle-boxes. The creativity could not be a question of random combination of habits, as Watson suggested. Hull's first reaction to the book is shown in this note of May 9, 1925:

> I have just finished reading Köhler's "Mentality of Apes". It is a splendid piece of work. I liked especially his criticism of the association theory. I found that it bore especially upon the mechanism of purpose.
>
> It is quite clear that my previous consideration of purpose was in a very simple form. Köhler raises the problem in an acute way

> when he considers *purposive thinking*. The question is: By what association mechanism could it come about that a secondary subject could be introduced as a means to attain a primary objective? (Hull,1925, w.p.).

As a first explanation, Hull considered purpose, an organic stimulus belonging to the pattern, together with the outer stimuli. He hypothesized a "transfer of purposes," in the sense that the purpose of catching the small stick was transferred to the long one lying outside the cage, by virtue of the similarity between the behaviors of reaching the stick and the banana. The internal stimuli of purpose provided a basis for the generalization.

In the *Idea Books* of this epoch, Hull recorded many disagreements with Watson's classical behaviorism. For instance, he could not accept that mental images were simple reinstatements of movements elicited by objects, because thinking habits were more general and flexible than ordinary ones. Instead of mere repetitions of behavior chains, they were new products resulting from the interaction among the units of habit. Fully aware of this fact, he proceeded to delineate the main mechanisms underlying these processes.

A SYSTEM OF MECHANISTIC PSYCHOLOGY

At the end of 1925, after the success of his correlation machine, Hull imagined a "psychic machine" that could perform mental operations. Guided by the analogy of the machine, he delineated the first two principles of the new theory: the *persisting stimulus of the purpose* and the *common response to different stimuli.* The persisting stimulus principle explained goal-oriented behaviors and general habits, such as making a detour whenever an obstacle blocked the way. The common response mediated conceptual abstraction where there were no identical elements, a process that would later be known as "secondary stimulus generalization" (Hull, 1939).

In February 1926, Hull wrote that "the more I study reasoning the more I am convinced that this business of purpose, whatever it physiology may be, is central. It is the thing that guides the associative processes. Without this there would be no persisting action whatsoever" (Hull, 1926-27, p. 38). Immediately afterwards, his thinking stopped on the "hunger pangs" produced by stomach contractions, a notion which he got from Walter Cannon's experiments on physiological drives (Cannon, 1912,1915). This local stimulus, according to Hull:

> Impels to more or less random acts. When this results in stimulation, which touches off the consummatory reactions, conditioned responses are set up and learning or habit has been set up.
>
> When hunger is part of the pattern and random movements have exposed the tense organ (eye) to a part of the stimulus pattern, this combination will at once induce the eating because it has done so before, *though the outer circumstances are largely* different. It is a case or redintegration (Hull, 1926-27, pp. 38-39).

The "hunger pangs" were instrumental in the formation of the general habits of food seeking. Let us assume that the seeking reactions become stimuli to some habit units. Then, the physiological condition of seeking becomes generalized, so that when certain internal tension common to certain kinds of seeking is connected by chance to a stimulus such as the stick, this action generalizes to other similar situations. Hull went on to say that this notion of internal tension, common to various seeking behaviors:

> Seems very promising. It is obvious that for this purpose it would matter little what the tension was or how small and otherwise unimportant it might be, it could serve as a stimulus to other action of any particular magnitude. The great thing would be that it would offer a possibility for a generalization process to get set up.
>
> Thus, the habit of walking is generalized. If we come to a rise in the path whether earth, rocks, ice or what, we go up and over. We react to the parts of the situation similar to previous ones in our multitudinous experiences in learning to walk.
>
> In a similar way, the multitudinous experiences of handling various shaped objects, with a given tension acting as a more or less continuous part to the pattern and the various complex visual and other parts to the pattern, the particular shape of the object will likely be disregarded (*unless it has a place in the dynamic pattern)*(Hull, 1926-27, pp. 41-42).

The general habits were especially active in Köhler's experiments. Let us imagine that the chimpanzee has to climb a box and use a stick to handle the banana hanging from the ceiling. He has separately learned the habits of climbing the box and handling food with sticks; the first to be activated is the handling the stick, and then going up to the box, which is weaker. After failing to get the fruit, the animal will combine them in a sequence, and this combination will be successful. Then the habit of uniting behavioral segments will generalize to other situations in which the hunger pangs are prominent. The relationship between these general habits and intelligence did not escape him: "With thoroughly intelligent persons there would be no difficulty in this generalization because the

subsidiary generalization would be a sufficient guide" (Hull, 1926-27, p.46)

However, the biological drives did not play a relevant role in conceptual thinking, where it was difficult to single out an organic need to be satisfied. This consideration led Hull to the principle of the *common response* to a series of stimuli.

Let us suppose that R is a response conditioned to three stimuli - *a, b, c* - which are quite different and have nothing in common. After the conditioning, they will be equivalent in eliciting R, and the kinesthetic stimulus produced by this response will be the element identical to all of them. Fully impressed by the new insight, Hull wrote, "It is just possible that if this principle were elaborated into a systematic work it might mark a new epoch (...). It is really a psychology of associated hierarchies. This is a very bad term as it is too clumsy in use (...). Despite the logical absurdity of this, practically it is of extraordinary importance" (Hull, 1926-27, p. 56).

By the end of 1926, Hull drafted a third principle after observing the phenomenon of the anticipatory movements in the learning experiments. When a rat is approaching a turn in a maze, he begins his turning movements before reaching the corner, and tends to make mouth movements when approaching the food box. These anticipatory movements could explain the short-circuiting of learning processes.

In December 1926, he wrote the first draft of a behaviorist theory of "the nature of theory" based on the deductive method. Encouraged by these progresses, by the end of 1927 Hull decided to publish a series of theoretical papers that later could be gathered in a "magnum opus," whose possible titles were: "Psychology of the Thought Processes. Psychology of the Thinking Processes. Mechanisms of Thought. Mechanisms of Mind. Mental Mechanisms. Mechanisms of the Mental Life. Psychology from the Standpoint of a Mechanicist" (1927-28, p. 67).

Hull was firmly decided to try out a psychology of the mental processes that avoided the shortcomings of the early behaviorism, and gave an adequate answer to the criticisms of the Gestalt. Such psychology would be systematic, that is, deductive, and quite reliant on the principles of mechanics. His main concern was to work out "a consistent system of mechanistic psychology" (Hull, 1927-28, p. 1).

FROM THE PSYCHOLOGY OF THINKING TO THE LEARNING THEORY

These projects never came to fulfillment because a little later, Hull became more and more interested in the theory of learning. The process of change started in January 1928, when Hull read for the first time

Conditioned Reflexes (Pavlov, 1927), and culminated in 1934 with his victory over Edward C. Tolman (1886-1959) in a public debate on learning at the annual meeting of the APA.

The main factors influencing Hull were the following:

1. The English translation of Pavlov's *Conditioned Reflexes* (1927), the "great book" as he used to call it. When it came into his hands, he was struck by the fact that such a simple process as the saliva reflex could give rise to theoretical principles more sophisticated than Thorndike and Watson's. Due to Pavlov's influence, Hull's first theoretical article did not deal with thinking, but with "A functional interpretation of the conditioned reflex" (Hull, 1929).

Hull's admiration for Pavlov became greater in 1930, when he studied the main philosophers as a preparation to formulate a new theory of knowledge. Even the most liberated of them, David Hume (1711-1776), took subjective experience as the starting point. Deeply disappointed, in March 1930, he decided to invert the philosophers' scheme and begin with action and habit. The study of thinking would come later, after discovering the elementary principles of behavior.

2. The reaction of the scientific community to Hull's theories was an external factor that meant a great deal to a person so eager for public recognition like him. While his learning models were met with general applause, his theory of knowledge was rejected as materialistic. The *Zeitgeist* was ready for learning, especially after the theories of Thorndike, Pavlov, and Tolman gained prominence on the psychological stage.

3. The logical positivistic philosophy of the "Vienna Circle," which brought a change of attitude toward scientific theory. Although Hull's relationship to this school is not so deep as it was generally supposed (Smith, 1986), due to its influence his theorizing found a favorable echo among psychologists.

4. The Institute of Human Relations of Yale University. In 1929, Hull was called as an expert in aptitude testing, hoping that he would contribute to the interdisciplinary study of social problems, which was the Institute's main goal. But when Mark May (1891-1977) took office as director, the Institute adopted a more theoretical orientation. A psychologist interested in the unification of social and behavioral sciences, May endorsed Hull's attempts to unify the theories of Thorndike and Pavlov in a formal system. With this institutional help, Hull was able to gather a team of young researchers that made the Institute the most dynamic center in American psychology at the time.

In July 1928, Hull taught a summer course at the University of Chicago, and took the opportunity to announce his cognitive projects to the members

of the department of psychology, led by Louis L. Thurstone (1887-1955). The response could not be more disappointing, as it is indicated in this *general note* of July 14: "Thurstone remarked that since I proposed to give an account of all the recognized processes I would write a darn good psychology, injecting the words "stimulus-response" here and there more or less at random which (seem to imply) would probably spoil an otherwise good book" (Hull, 1962, p. 825).

One person in the audience pointed out the risks of the stimulus-response approach and advised Hull to look for a less dangerous one. His first reaction was to reaffirm himself in his purposes, but after some reflection, he decided a change of tactics. Instead of wasting his time on explanations that did not convince anybody, he would try to formulate a materialistic theory of knowledge that would destroy once for all his adversaries' mental fictions.

This philosophical enterprise supplied the context to "Knowledge and purpose as habit mechanisms" (1930). The psychology of knowledge was a necessary step in order to deal with the problem of the nature, origins and limits of human knowledge.

In early March 1930, Hull started writing the paper with great expectancies. On March 15, he did find the long expected name for the symbolic processes of thinking. They were "pure stimulus acts," that is, acts without instrumental functions whose sole function was to produce the internal stimuli that were the behaviorist equivalent of the ideas. The discovery was a "fortunate accident":

> It just popped up "by itself" as it were, while I was writing out some detailed notes for the paper before actually writing it. I have given the matter a good deal of thought for several years past but never thought of it on exactly that level before. I have usually thought of symbolism on a much higher (and probably much less significant) level, so far as the understanding of the evolution of symbolic series is concerned (Hull, 1928a, p. 146).

"Knowledge and purpose" explained how a physical object, the organism, could incorporate another physical object, the outer world. That was because the worldly sequences evoked parallel organic reaction sequences that, by the principle of association, acquired a tendency to run off by themselves, independently of the original world sequences. These internal sequences were functional copies of the world sequences that allowed the organism to react to the not-here and the not-now, giving it a greater "degree of freedom."

The anticipation of the final stimulus of the worldly sequence, due to the greater speed of the symbolic habits, was the physical substance of

foresight. When both sequences start at the same time, but the organic one runs off at a faster rate, then the end-reaction of the subjective series actually antedates the stimuli that evoked it. Without explicitly quoting him, Hull was following the early behaviorist Albert P. Weiss (1879-1931), who also linked foresight with the terminal responses in his book *A Theoretical Basis of Human Behavior* (1925, pp. 350-351).

Finally, Hull explained the great economy of sequences of pure stimulus acts with the mechanism of *purpose,* or *persisting stimulus*. It could be a continuous red light, the continuous gripping of a dynamometer, the continuously recurring hunger cramps of the digestive tract, or whatever. What really mattered was that this persisting core of sameness in the stimulus complexes became associated to all reactions in the sequence. The multiplicity of excitatory tendencies thus established was then followed by competition among them. If the persisting stimulus were more strongly conditioned to final responses, then these would overthrow the intermediate ones and the habit would be "short-circuited". The stronger conditioning to final responses, which would later give rise to the "goal-gradient hypothesis" (Hull, 1932), explained the elimination of the intervening acts in symbolic habit sequences.

On May 25, 1930, Hull explained goal attraction and directing ideas with the *fractional anticipatory goal reactions* (r_G), a notion that was a development of the anticipatory movements observed by Hull in 1926. In instrumental habits, such as maze running, the goal response anticipation would interfere with the running and thus prevent reaching the food. The biological economy required the anticipation of only a small fraction, which did not disturb the running.

The proprioceptive stimulus (s_G) of this fractional anticipatory goal reaction gets conditioned to all the responses in the sequence, the same as the persisting stimulus of purpose. But it gives a more specific direction to the behavior, because from a single drive stimulus there may evolve many tolerably distinct goals. For example, when hungry, a rat eats many different kinds of food.

This new mechanism explained Gestaltist's goal attraction and William James' ideo-motor action, as Hull indicated in the article "Goal attraction and directing ideas" (1931). It was also acting in the equivalent *habits*, or habits sharing the same goal response and the same starting point. Hull already had the principles that he used in the papers on the "directing ideas" (1931) and the "concept of the habit-family hierarchy and maze learning" (1934a).

In July 1930, Hull experienced again the opposition to his cognitive ideas, this time at the University of Harvard. The first confrontation was

in a private meal with the Princeton philosopher Edward G. Spaulding (1873-1940), who was quite contrary to the idea that habit could generate novelty because it was repetitive (Hull, 1930-31, pp.20-31). At the end of July, Hull explained his theory of knowledge to Harvard's faculty, apparently without much success. According to his testimony: "The most of them were ready to agree that habit could really produce novelty. They objected to the propriety of my calling the temporal antecedence of R_5 to S_5 a case of foresight or of the parallelism of the lower series a case of knowledge" (Hull, 1962, p. 842).

On August 4th, Hull took notice that the vast majority believed that he had suffered a personal defeat in the debate with Spaulding. This was particularly depressing because "there seems to have been no interest in the problems themselves. (...) Practically no one has any grasp of what I am trying to do, much less of what I have accomplished (...) There is a tremendous resistance to change" (Hull, 1962, p. 844).

In view of this hostility, Hull decided to avoid philosophical confrontations, but this was too painful for him because "I am actually so intense and serious about it" (1962, p. 845). Finally, on August 9th, he thought of naming his system "Physical Psychology," because, among other reasons, it had "the philosophical advantage of avoiding certain traditions and stigmas associated with the term *matter*. It won't, at least for the present, raise the question as to the ultimate nature of matter" (Hull, 1962, p. 845).

The circumstances forced him to avoid philosophy in order to keep his reputation untouched. By contrast, the more neutral theory of learning was met with general acceptance.

THE DEBATE WITH TOLMAN

In fall 1930, Hull got a detailed account of Tolman's experiments in California after reading "The Effect of Removal of Reward on the Maze Performance of Rats" (Bruce, 1930). A little later, in May 1931, he started experimenting with rats in the maze.

The publication of *Purposive Behavior in Animals and Men* (Tolman, 1932) was an important event for learning theory because of the number of maze experiments that it presented and also for the theory that accompanied them. On January 24, 1932, Hull wrote his first impressions about the book:

> Yesterday I spent three hours going through "Purposive Behaviorism". I think without doubt it is a real contribution to psychology. Upon the whole I sympathize very much with his emphasis on the purposive aspects. I will require careful reading

> to be sure but I don't think I agree with him at all in his skepticism of the synthetic approach, his utter neglect of the bearing of the conditioned reflex results on the more complex forms of learning and the possibilities of deductive and synthetic explanations of the more complex processes in terms of simpler ones. He seems to agree substantially with Köhler that a generalized description of the behavior in isolation to the situation as a whole is quite as far as now possible of for some time to come (Hull, 1931-33, p. 94).

One year later, in January 1933, probably as a result of the influence of Tolman's book, Hull introduced a substantial change in his "magnum opus." Instead of dealing with mental process, it would be a book on human adjustment. As he wrote in the "Plans for the New Year":

> This future ought to lie in an intensive study, both theoretical and experimental, of the problems of human adjustment. This involves, at the outset, an intensive investigation of the phenomena of the conditioned reflex (Hull, 1931-33, p. 170).

Tolman's criticisms to the reflex conditioned theories disturbed Hull, especially those directed against him in a popular text of comparative psychology (Tolman, 1934). According to Tolman, Hull's theory had two shortcomings: the goal response could not be conditioned to all the stimuli in the maze because there was no temporal contiguity. And, secondly, the goal gradient hypothesis belonged to the field theory.

In July 1934, in a long note, Hull dismissed the first objection by claiming "his theory was an associative system, rather than a strict conditioning system" (Hull, 1933-34, p. 291).

The second criticism was more dangerous, because it questioned a pillar of his theory. The goal gradient hypothesis, as John A. Mills has remarked, "was paradigmatic because, in principle, it permitted Hullians to analyze a complex act into its components, apply conditioning principles directly to each of its components, connect the components with one another, and thus synthesize the theoretical analogue of the complex act itself" (Mills, 1998, p. 107).

If the goal gradient were a field theory hypothesis, then all his efforts to defeat the Gestaltists would be doomed to failure. The objection, however, was the expression of a subjectivism improper in a scientist. Attributing spatial knowledge to rats was the same as saying "that the parabolic trajectory of a projectile implies that the projectile in some sense knows where the earth is as well as the mathematics of parabolas" (Hull, 1933-34, p. 293). Tolman described animal behavior in anthropomorphic terms, without giving an adequate explanation. For this reason, Hull went on to say: "In case I ever write an attack of any kind on Tolman, it would be

well to give a very brief but concentrated attack on anthropomorphism itself on the grounds that it provides a pseudo explanation of natural phenomena" (Hull, 1933-34, p. 299).

A few days later, however, Hull changed his mind and decided to organize a round table on learning at the APA meeting to be held at Columbia University in New York. That was an excellent occasion to attack Tolman's weaknesses before the leaders of the psychological establishment. According to his plans, the debate took place on September 7, 1934, under Harvey A. Carr's supervision and, for the first time in his life, Hull experienced a sense of victory. As he wrote to S.A. Switzer:

> The upshot of the whole thing was that Tolman practically admitted that he had never seriously attempted to make logical deductions for his system, claiming for it little more than that it suggested to him a large number of interesting experiments. He seemed to be distinctly on the defensive, and said he thought he had a right to go on thinking in that way if he found it satisfying and if it suggested lots of interesting experiments to perform. I, of course, admitted quite freely that his experiments had been very ingenious but emphasized the distinction between the merit of fertility which might be possessed by a mere point of view and the merit of truth which must be possessed by a theory if it shall be entitled to any status is science as in theory. The whole thing went off with the utmost good nature on the part of every one and I believe the crowd found the discussion most stimulating and enlightening (Hull, 1934b).

Tolman was forced to recognize Hull's logic superiority before the audience. The exhibition of formal rigor at a moment when logical positivism entered the American scene was so convincing that Richard M. Elliott (1887-1969), the editor of a psychology collection in the prestigious Appleton, requested him the right to publish a book on psychological theory. And, together with Edna Heidbreder (1890-1985), invited him to give a talk on scientific method at Columbia University. In view of these facts, Hull decided to concentrate all his efforts on learning theory:

> As an upshot of these various things, I have at last been enabled to reach a decision on the question, which has baffled me all past year. I have definitely decided to do the work on theory first, and leave the matter of the conditioned reflex to be treated incidentally, though possible very effectively nevertheless.
>
> Al of which is extremely fortunate since as a result I shall be able to avoid the further scattering of my energies by concentrating definitively on those experimental problems which will bear most

> definitely and critically upon the theoretical system and, more specifically, upon experiments which will find a place as pertinent evidence in the projected work (Hull, 1962, p. 857).

From this moment on, Hull worked only on his theoretical system. Realizing that systematic theory was the easiest way to the triumph over his rivals, he built up a complex mathematical-deductive theory of learning, based on the reinforcement principle. In his "magnum opus" on the *Principles of Behavior* (Hull, 1943), he took a physiological stance and explained reinforcement as biological drive reduction, in spite of the many problems of this notion. As he wrote on January 19, 1942:

> It has struck me more and more forcibly of late that my system is especially defective on the motivational side. Instead, it may well be that this is the major difference between Tolman and myself. Tolman is an associationist, much like Guthrie, but stresses the incentive aspect of motivation e.g. in his latest learning experiments. It is this incentive aspect of motivation which is the central factor in Tolman's insistence on the role of expectancy in behavior situations (Hull, 1941-43, p.172).

In early February, he read Guthrie's article on "conditioning as learning principle" (Guthrie, 1930) and wrote: "This I think is the most brilliant article of his I have ever read. I wish I had seen it ten or twelve years ago. My own system might now be rather different" (Hull, 1941-43, p. 194). He was quite aware of the limitations of his motivational theory, but he held consistently to it, probably influenced by the experiments of Frank Beach on sexual motivation (Beach, 1942).

INSIGHT AND SIMILARITY

As soon as the manuscript of *Principles of Behavior* was completed, Hull began to write the second volume of the "magnum opus," which dealt with the deductive explanation of the more complicated phenomena of individual behavior. However, the system of learning quantification kept him busy for many years and the publication of *A Behavior System* was delayed until 1952.

On March 17, 1951, Hull considered the feasibility of including a chapter on abstraction and conception before dealing with problem solving. "*One reason* – he wrote - *for putting the concept material is to complete the cycle of my life work back to its beginnings. This consideration will be decisive*" (Hull, 1949-1951, p. 144). But, after some reflection, he decided to leave it for the third volume on social behavior, where language would be treated thoroughly.

A Behavior System was basically a study of the different classes of animal learning. Hull returned to the old r_G notion, which was now called "fractional antedating goal reaction", to explain Tolman's expectancies, double-drive learning situations (Kendler, 1946; Leeper, 1935), latent learning experiments, and other habit problems.

In the chapter on problem solving, he considered insight basically in the same way as in the article "The mechanism of the assembly of behavior segments in novel combinations suitable for problem solution" (Hull, 1935). The chimpanzees' insightful behaviors were the result of joining two different habit segments, which shared some common reactions.

Hull started with N.R.F Maier's experiments on rats' insight (Maier, 1929) and his definition of insight as the ability of joining together spontaneously two habit segments without having them previously associated by contiguity. Then he proceeded to deal with spontaneous tool-use acquisition, taking into account Jackson's (1942) and Birch's (1945) experiments with chimpanzees, by which insightful tool using was impossible if the chimpanzees had not previously learned habits of manipulating sticks in play. They will not use the stick until they have learnt its instrumental use. This learning is necessary for using sticks as a functional extension of their arms and hands.

According to Hull, manipulation of the stick involves grasping and other muscular activity quite different than simply reaching for a banana and eating it. However, the movements and the associated tactile stimuli are quite similar to those involved in touching objects with fingers. For instance, the distance separating the two decreases continuously and the resulting changes in manual pressure coming indirectly through the stick somewhat resemble the pressure stimuli coming from a touch with fingers and so on. In a word, Hull wrote:

> The novel behavior mechanism which is mainly instrumental in the unique behavior displayed in what we have called insight, is the antedating goal reaction which is characteristic of behavior segments. It is this identity of fractional antedating elements which bridges the gap left by the lack of associative contiguity mentioned by Maier. Thus we find ourselves reverting in a sense to association by similarity, proposed by William James (1890) in his attempt to explain rationality some forty years ago (Hull, 1952b, p. 325).

After more than 20 years of intensive work in learning theory, Hull returned to James' association by similarity, which was the starting point of his doctoral dissertation. This time the identical element in the different situations was not the purpose, as he suggested in 1925 after reading Köhler's *Mentality of Apes*, but the fractional antedating goal reactions of

the animal, which were instrumental in the stimulus generalization process.

Once he had finished *A Behavior System*, Hull decided to begin the third volume on problem solving and conceptual abstraction. On March 29, 1952, he drafted a brief sketch of an article on "Elementary Human Problem Solving" (Hull, 1951-52, p.97), and on April 12, 1952, he planned another paper on "Concrete Inference in Man" (1951-52, p. 101.). He defined inference as "some sort of novel generalized reaction which solves a problem, i.e. attains a R_G in a novel way" (1951-52, p. 102). Then he considered concepts as generating definitions, and asked how definitions solved concrete problems.

A week later, on April 21, Hull defined inference as "*the generation of a new habit by or from some olds habits*" (Hull, 1951-52, p. 103), and ended his reflections by returning to concept discrimination. His thinking came again to his doctoral dissertation: "The concept discrimination in my thesis is the (12) various responses. Thus if several all or none situations are combined, we have *several different responses* (...). If this is true, there is interest in the multiple-response situation" (Hull, 1951-52, p. 104). This was practically the last idea registered in his notebooks before his untimely death.

At the end of his life, Hull came back to his doctoral thesis project, but it was too late and his "magnum opus" on reasoning remained unfinished. However, his attempt to explain mental processes was not without precedents in the American Psychology. It was in line with the tradition of William James and Edward L. Thorndike, the main inspirers of his thinking. Hull tried to find out the physical basis of similarity, an associative law that introduced a factor of complexity in the explanation of the human mind and was left aside by J.B. Watson, the founder of behaviorism. Clark L. Hull accepted similarity as the key to understanding human intelligence. He tried to explain it in terms compatible with the primitive machines of his time, and created a set of theoretical constructs that now seem outdated because of technological progress. But his attempts to find out the physical basis of similarity should not be neglected, at least in order to make justice to all the complex aspects of this theorizing.

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