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The Origins of Cognitive Science: A Tale of Many Meetings

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ABSTRACT

With its intellectual origins predating the birth of the discipline and born to many contributing domains, Cognitive Science has had an uncharted but a fascinating growth. While the inadequacy of resources available and the absence of historically sensible narratives prevent stringing together a sequence of influences crucial to the meandering and transition of focus areas in Cognitive Scientific works, on the other hand, the many meetings and its theme, the participants and their works, hold vital clues to the coming into being of a nouveau science. This paper investigates the gradual growth of the discipline from the perspective of many meetings held and keeps a tab of how Cognitive Science has progressed in close correspondence with the overall advances of science and technology, over the years.

17th C had all that was necessary for Cognitive Science to come into being, but the moment wasn't ripe enough, technology was rudimentary and science not quite equipped to deal with investigations of the mind-brain-consciousness triumvirate. It wasn't until mid-20th C that Cognitive Science took the shape of a discipline and managed to bring together several disciplines under a unifying research paradigm. Initial progresses came from a few windows of opportunity, for example – language impairment after a stroke/head injury gave important insights about the organization of language and its instantiation in the brain, rapid succession photography helped visualize/analyze motion perception, single neuron recording methods led to recording neuronal transmissions in giant squid axons and discuss their nature of connection and communication within the brain, logic and computation attempted to apply mathematical principles to nervous system functions, measures to ameliorate diseases of the nervous system, drug-resistant recurrent epileptic seizures led to experimental treatments producing fundamental knowledge about brain functions, technological demands of the world wars (rapid communication solutions, deciphering military codes, calculating artillery fire trajectories etc.), works of individual stalwarts on problem solving behaviors, schemata in memory formation, internal mental-models, curiosity driven attempts to model the ways children comprehend the world, advances in computation, automation and electrical circuits – all set the ball rolling for something new. Indeed, the convergence of it all provided a basis for the emergence of Cognitive Science not exactly as a coherent, integrated science, but as a loose interdisciplinary coalition of independent disciplines; some descriptive and empirical (Cognitive Psychology, Linguistics, Neuroscience, Cognitive Anthropology), speculative and foundational (Philosophy), and, both speculative and applied (Artificial Intelligence) – united and sustained by a motivation to understand, explain and simulate; the working mind, brain, behavior and consciousness, in man, animals, and replicate the same artificially in machines.

Though lacking an agreed upon set of laws, definition, meaning, content, scope and objective expected of a science, the central tenet of the emerging interdisciplinary field was oddly resilient – aim for a complete understanding of the mind and the brain by studying/analyzing every related phenomenon from multiple perspectives such that it creates a better understanding of the processes that gives rise to a behavior. No science in history has ever flourished in isolation. Of crucial importance are factors like the social-economic-cultural-political flux across geographical space and time creating the need for certain sciences to emerge, evolve, shift its research focus and determine the scientific temperament of the time. Also catalytic to the growth of a scientific discipline, without exception, are collaborations among people in pursuit of similar studies, under the banner of an institution, study/research programs offered for those interested amounting to a degree, provisions for an exchange of ideas through student and faculty visiting fellowships, mobile PhDs, sharing research finds by meeting at regular intervals, forming reading groups, initiating brainstorming sessions, and having its own set of journals, periodicals etc.

The initial years of Cognitive Science explored in this paper too is one of interdisciplinary exchanges, many meetings (instrumental in bringing important participants together), mushrooming of centers of research and education and Cognitive Science societies and journals.

1. Noteworthy among the initial meetings were

1.1. New York City meeting (1942)

The first meeting, at the New York City, sponsored by the Josiah Macy Jr. Foundation (which in the long run had a vital role in the birth of Cognitive Science) focused on topics of the nervous system. Warren McCulloch and Arturo Rosenblueth presented works suggesting that aspects of mental activities could be modelled with neural networks. This was inducted in mathematical models later by connectionists while Rosenblueth showed that goal directed behavior could emerge in systems with feedback loops.

1.2. Winter meeting in Princeton (1943-44)

With participants like McCulloch, Walter Pitts, Lorente de Nó, John Von Neumann and Herman Goldstine; this meeting was an unprecedented coming together of stalwarts in formal logic, neural nets, neuroanatomy and computation. Lorente demonstrated in elegant anatomical works that within the cerebral cortex there are circuits instantiating loops critical to maintaining memory within the brain. Donald Hebb's in his book 'The Organization of Behavior' presented a novel approach in merging Psychology and Physiology to explain cognitive functions, the effects of sensory deprivation, stabilization of visual inputs to the retina, impact of deprived/enriched hearing conditions etc.

1.3. Ten Macy Foundation Conferences on cybernetics (1946-53)

Warren McCulloch was the major force behind it. No written records exist of the first 5 meetings but proceedings of the last 5 were published (Encyclopedia of Cognitive Science, Introduction, Publisher: Macmillan, Editors: Massimo Piattelli-Palmarini and Lynn Nadel). Over these interdisciplinary meets were discussed ideas central to cybernetics such as control, feedback and communication. Among those present were anthropologists Gregory Bateson and Margaret Mead; Neurophysiologist McCulloch; Mathematician Wiener and Von Neumann; information theorist Shanon; psychologists Kluver and Lewin. Their fresh perspectives began dominating Cognitive Science in the 1950s.

1.4. Caltech Hixon Symposium (1948)

Attended by some of the participants of the Macy Foundation Conferences, the Caltech Hixon Symposium was presided over by Henry Brosin (psychiatrist). The proceedings of this symposium were published in 1951 and among the significant papers presented include Von Neumann's 'The General and Logical theory of Automata' and Lashley's work on 'Serial Order'. Behaviorism was vehemently opposed, to an extent where Lashley began pointing out parts of the stimulus – response theory implausible.

1.5. Second Symposium on Information Theory at MIT (1956)

Hosted at MIT between September 10 – 12, 1956, the symposium was so significant that George Miller earmarked the second day of the proceedings (11th September 1956) organized by the MIT Special interest group in Information Theory, as the moment of conception of Cognitive Science. The morning began with a paper by Newell and Simon on 'Logic Theory Machine', followed by a paper from IBM (by Rochester and collaborators); where they used the-then largest digital computer available; an IBM 704 with a 2048-word core memory, in a (failed) effort to test Donald Hebb's Neuro-Psychological theory of Cell assemblies. Victor Yugve next talked on the statistical analysis of gaps and its relation to syntax. Noam Chomsky spoke about transformational generative grammar and showed how linguists could produce results with mathematical rigor. While every linguist was busy claiming that language has all the precisions of mathematics, Chomsky was the first linguist to prove it. The paper he presented here was later expanded into a monograph; 'Syntactic structures' – is attributed to have initiated a cognitive revolution in Theoretical linguistics. George A. Miller talked about the limits of Short-Term Memory, while Swets and Birdsall explained the significance of signal detection theory for perceptual recognition. Miller concluded the symposium on a happy note believing that experimental psychology, theoretical linguistics and computer simulation of cognitive processes were all pieces of a larger whole and the future would soon see a progressive co-ordination of their shared concerns for an emerging new science.

1.6. Dartmouth Seminar on Artificial Intelligence

1956 has been a crucial year for the development of Information Processing Psychology. The Dartmouth research seminar on Artificial Intelligence was attended by luminaries like John McCarthy, Marvin Minsky, Nat Rochester, Claude Shannon, Oliver Selfridge, Herbert Gelernter, Alan Newell and Herbert Simon. Shannon and McCarthy discussed on 'Automata Studies'; a volume they edited together, while Newell and Simon pointed in their addendum to 'Human Problem Solving' that Minsky's essay; "Steps towards Artificial Intelligence" captures well the existing views of the time. This meeting too saw a mix of disciplines that would come to define much of modern cognitive science. There was a groping for methodologies that would allow scientists ask meaningful questions about mental activity and single-minded emphasis on behavior at the expense of cognition was at an end.

1956 was also the year Jerry Bruner, Jackie Goodenough and George Austin published 'A study of thinking' discussing cognitive strategies. Signal detection theory was the crux of the works by Tanner, Swets and Birdsall. George A. Miller in his article "The magical number seven, plus or minus two", described the limits of human capacities to process information. Ward Goodenough and Floyd Lounsbury's articles became models for research in cognitive anthropology. J.B Carroll edited a collection of papers by Benjamin Le Whorf on the effects of language on thought, while Roger Brown wrote extensively on his studies of first language acquisition. 1956 in short was a brilliant year for those interested in the theories of the mind, information theory, signal detection theory, computer theory and computers themselves. Many of these were riding the waves that began during the 2nd World War.

The closeness of Biology and Cognitive Science was falling apart, and when the early biologically driven approach to neural nets (as in perceptron models) failed, neurobiological simulations were unsuccessful, its limitations seemed too many, the research focus began to move away from Biology and tilted towards the next promising new thing; Artificial Intelligence. To understand cognition, they didn't bother to pay attention to the underlying biology. An era of symbolic modelling of mental computations, representations and artificial intelligence research without reference to real brains, blossomed.

Karl Lashley when talking of the brain-computer linking enterprise remarked, "we are more likely to find out how the brain works by studying the brain itself and the phenomenon of behavior than by indulging in far-fetched physical analogies". With Donald Hebb disagreeing on Lashley's opinion about the role of neural pathways, a schism developed and both being very influential in their domains, Cognitive Science and

Neuroscience developed separately after the 1950s. While Neuroscience rarely spoke to questions of interest to Cognitive Science, the latter proceeded within a symbolic framework needing little or no reference with the brain. The-then focus of Artificial Intelligence meanwhile catered to the interests of the war, and knowledge-representation computations. Cognitive Science next meddled in empirical studies while Chomsky, single handed, revolutionized the study of language. Among the many other interesting works were - Donald Broadbent's study on attention, Jerome Bruner and colleagues' work on thinking, Herbert A. Simon, J.C. Shaw and Allen Newell's General Problem Solver, Julian Hochberg on the role of memory and the internal factors of perception, George Sperling's work on visual memory, Arthur L. Samuel on Artificial Intelligence and mathematical neural networks, etc.

A landmark discovery of the 'reticular activating system' shifted attention back to the brain. It was no longer thought to be a passive organ waiting to respond to external stimulation, but constantly active. Curiosities took a root; what kind of activity did it engage in, endogenous and exogenous factors influencing brain functions etc. These had enormous implications. Those interested, flocked in numbers to the new institutes and centers of research mushrooming throughout the country. Example, the Montreal Neurological Institute (MNI); Penfield, focused on patients about to undergo surgery to control Epilepsy. Penfield and Rasmussen stimulated brain areas adjacent to the focus sites, as a means of determining which tissue should be excised and which spared. This led to the famous sensory and motor maps of the cortex within which the various body parts were represented in unusual proportions, along with affected views about the organization of information in the brain. Another important study was on a patient at MNI who had lost the capacity to memorize recent events, though he could remember snippets of times preceding the surgical bilateral section of a part of his Medial Temporal lobe – important for its role in memory formation. Also noticed was the capacity of the brain to learn new procedural tasks and how it finds its way through new environments, without an explicit memory. One study accounted for the efficiency of sectioning the corpus callosum to prevent the spread of epilepsy from one brain hemisphere to another. Research wasn't confined to observing 'split-brain' patients, but also included studies aiming to figure out a variety of cognitive functions carried out in the brain.

1.7. Two meetings by the Council for International Organizations of Medical Sciences (1950 - 59)

They brought together researchers from various fields to discuss implications of the Reticular Activating System. Proceedings of the respective meetings were published later as "Brain Mechanisms and Consciousness" and "Brain Mechanisms of Learning". Inclusion of scientists from USSR, Eastern Europe at the 2nd meet was noteworthy, as, the Cold War had precluded any such interaction.

1.8. Three annual conferences sponsored by the Macy Foundation & the National Science Foundation on the CNS and Behavior (1958-60)

Macy Foundation and the National Science Foundation next sponsored three annual conferences from 1958 - 60 on the Central Nervous System and Behavior. The first meeting aimed to bring Russian neurophysiology to the West. Though no USSR scientist was present, the works of Sechenov, Pavlov, Bechterev, etc. was the focus of discussions. The 2nd meeting broadened this base by including researchers from Eastern Europe – Bures (Czechoslovakia), Grastyom (Hungary) and Rusinov (USSR), while the 3rd meet had Luria and Sokolov themselves.

1.9. Moscow Colloquium on EEG of Higher Nervous Activity (1958)

This meeting addressed a wide range of topics (arousal, memory, perception, language, etc.) and brought together prominent neuroscientists from both the East and the West. The impact of the six meetings with its focus on the brain was immense. An entire generation of Cognitive Neuroscientists were weaned on books from these meetings. It was also believed that a careful study of Aphasia from a variety of perspectives could help understand language.

1.10. 6-week seminar at the Boston VA Hospital (1958)

This 6-week long seminar at the Boston VA Hospital, saw Aphasia discussed at length (proceedings were published later in a book). The seminar went along to inspire a series of other meetings soon.

1.11. London CIBA Foundation meeting & the London Symposium on International Theory of Mechanization of Thought processes (1958)

The focus here was on Aphasia as well. The meetings were interdisciplinary and though not related to mainstream Cognitive Science, important in setting the agendas of Cognitive Neuropsychology. It was also the year of the London Symposium on International Theory on Mechanization of Thought Processes at the National Physical laboratory.

1.12. MIT Seminar on Language Acquisition (1960)

1960s saw the consolidation of many areas of Cognitive Science. Psycholinguistics bloomed to an influential discipline thanks to Roger Brown and Chomsky among others. They formulated the basic approach to a modern study of language acquisition. Miller inspired psychologists for experimental investigation and Chomsky's theory of grammar took linguistics by a storm, for linguistics could now be tested in the laboratory. The cry was for 'one linguistic rule, one mental operation'. Subsequent researches however disproved this idea. Fodor and Garrett believed the relationship between grammar and behavior must be 'abstract' to some degree, Bever proposed models of comprehension and set the implication of these ideas in their joint book, "Psycholinguistics: acquisition, perception and production of language". Debates about the linguistic capacities of higher primates too had begun. Some proposed – there is an evolutionary continuity of all cognitive functions, but Chomsky stressed that the components of human language (Infinity, Recursivity, Constituency, Generation by autocuing etc.) are unique and without a counterpart in animal communicative systems, including the higher primates. Tests on

the linguistic capabilities of chimpanzees by primatologist David Premack and similar studies at the Columbia University testified that though fascinatingly intelligent and capable of sophisticated cognitive operations, chimps lack the central components of human linguistic competence (phonetics, phonology, morphology, syntax and semantics). Comparative studies between animals and humans were also extended to areas like vision/motor control/brain development/acoustic perception/categorization abilities etc.

Also searched for were similarities among languages, the biological evolution of language, bridging the syntax – semantics gap, exploring lexical structures, modelling language acquisition with mathematical tools, developing computational models of linguistic competence etc. The late 1960s' saw neuroscience progress and its contributions help Cognitive Science. A string of research came up with insights on how we see the world and why we see it in the way we do, how the brain treats vision – many based on the neurophysiology of primates. Brain structures like the Hippocampus; was investigated for its role in memory, location awareness and cognitive maps. Its synaptic plasticity was used to speculate about how learning occurs, memory-formation down to the cellular and molecular mechanisms involved, synaptic mechanisms and brain plasticity, etc.

1.13. Royalmont Meeting (1975)

The 3-day multi-disciplinary meet attempted to reconcile Chomsky's approach to language with Piaget's approach to cognition. Biologists questioned Piaget's reliance on auto-regulation without specific pre-existing regulators and his attempts to re-introduce notions of the inheritance of acquired traits. François Jacob believed regulations occur because regulatory genes regulate metabolic pathways. Chomsky enumerated the basic facts about language while Fodor argued that conceptual novelty and potency of a pre-existing language could not be the result of learning. Some participants defended Piaget, others sided with Chomsky and Fodor. Their diversity ranged from Molecular Biologists, Neurobiologists, Philosophers, Anthropologists, Ethologists, Mathematician, Logicians etc. addressing core issues like;

- Modularity of mind and autonomy of Syntax.
- Innate cognitive structures and the poverty of stimulus.
- Reasons to reject them.

They discussed about the impoverished environment of cognitive science and if it is possible to ensure a steady growth of the discipline. Chomsky staunchly argued for the 'autonomy of syntax' and among others; showed some specific syntactic principles common to all languages, and integral to our 'knowledge of language'.

The early 1970s saw Endel Tulving suggest there may be two different kinds of human memory – episodic and semantic. Three papers (by Gaffan, Hirsch, Nadel and O'Keefe) suggested the same, but on animals. Edward Toleman in a classic 1949 paper; had stated; "There is more than one kind of learning." Discussed again in 1978 by O'Keefe & Nadel for human and animal 'cognitive map theory', it was applied within the human amnesia literature by Kinsbourne, Wood and others. The general notion was that there are multiple neural modules concerned with different kinds of memory. Studies on visual cognition also began with the work of Ungerleider and Mishkin.

Jerry Fodor published 'The Modularity of Mind' (1983); proposing that the brain is comprised of many specialized modules. The challenge lies in figuring out how these interact to generate cognition and behavior. 1970s and early 80s witnessed considerable strides made in the study of mental imagery, mental rotation, concept and category formation, biases and heuristics in natural reasoning and decision-making, memory, abstraction, motion perception, cognitive – conceptual development in children, learnability etc.

A major shift was the revival of biologically inspired approaches to Cognitive Science beginning with the San Diego 'connectionist movement'. The assertion that cognitive models should look closely at Biology saw the focus directed on distributed representations and learning algorithms. Hebb's 1949 idea of connectionism resurfaced in mid 1980s as a new approach to neural networks with a major impact on Cognitive Science. John J. Hopfield (in 1982) developed neural networks capable of automatic learning, rule extraction and generalization inspired by real neuronal circuitry. Mathematical simplification of neural networks not only allowed an analysis of behavior but also helped model and mimic (automate) activities like learning. This was a sensational feat, its efficiency in extracting similarities from inputs equaled and often surpassed humans. Ascent of connectionism in Cognitive Science went hand in hand with Neo-Piagetianism touting virtues of general intelligence, cognitive mechanisms powered by processes like step-wise abstractions, categorizations, thematizations and generalizations. Arguments, counter-arguments and debates between the two proponents remain till date.

1.14. Annual International Conferences of the Italian Cognitive Scientists at the University of Padova (1980)

Cognitive Neuropsychology flourished brilliantly in Italy with international acclaim. Since early 1980s', the annual international conferences held (every January) under the University of Padua regularly saw the Italian contingent of Cognitive Neuroscientists assemble along with colleagues from other countries. Tremendous discoveries made possible by the technical advances helped record activities from individual neurons in response to carefully controlled inputs. Works of Mountcastle on the somatosensory system, Hubel and Wesel in visual system, were seminal. The tradition of such studies has continued till date.

1.15. A series of lectures at Scuola Normale in Pisa (1980)

Theories of learning in first language acquisition have been the crux of the series of discussions at the Scuola Normale, Pisa (1980) before being published in a book. It introduced a 'principles and parameters' model reducing all differences between human languages to a small universal set of syntactic nodes, each with a choice between only 2 binary values (labelled as (+) and (-)). The child learning a native language was thereby supposed to be fixing binary values set by his surrounding community. James Higginbotham termed this as 'switches on a mental panel'.

2. Getting closer to the technologies of the time

2.1. Imaging Technologies

Cognitive Neuroscience had a fantastic run in the last couple of decades, largely due to the advances in neuroimaging techniques making it possible to study the human brain engaged in various cognitive activities. EEG recording during various cognitive activities was insightful, but surface recordings had its limitations, especially with spatial localization of the recorded signals. Event Related Potentials (ERP'S) recorded on cognitive events of interest, showed the patterns of brain activation related to those events. It gave insights, but spatial localization remained unaddressed – this is where new techniques of neuroimaging were more useful. Methods were increasingly devised to track metabolic and other consequences of neural activities in people. The Positron Emission Tomography (PET), for example, used radio-active substances and noted on its absorption by neural tissues. A less invasive alternative to come up was the fMRI (functional magnetic resonance imaging). It took advantage of the fact that blood oxygenation levels change with neural activities and oxygenated/de-oxygenated blood (the hemoglobin) have different magnetic properties thus allowing detection with powerful magnets those brain-areas mobilized by some cognitive activity. Magneto-encephalography (MEG) followed next. It depended on small but measurable magnetic fields engendered by neural activities and had the ability to couple real time dynamic response with accurate spatial localization. Trans-cranial stimulation (TMS) emerged as a method to stimulate selective areas on the cortical surface to study its role in various cognitive functions. Together, these imaging techniques ushered an explosion of research on the brain mechanisms of human cognitive functions.

2.2. Old wine in a new bottle

While most of the previous studies were an analysis of functional deficits, in pathological cases and assumptions about which parts of the brain are engaged in what kinds of cognitive activity, the focus of imaging studies shifted from the centres of cognitive function to interactions between multiple brain areas. Researchers are still at it, meeting, studying, researching and using every scientific knowledge and technological support to develop newer means to advance cognitive modelling and brain imaging techniques. Traditional methods too are being innovatively reimplemented, e.g. 'mirror neurons' demonstrate a remarkable property: the same neuron is active when an animal engages in an action, or observes another animal engaging in the same action. It has a role in creating internal mental models and has found a way in discussing the emergence of language. Simultaneous recordings from many neurons enabled a study of the activity of neural ensembles, Neuro-anatomical studies overruled the view that nerve cells cannot be formed after the early years of life, studies of memory and perception, gave neuroscientists an idea of the incredible dynamism of the brain, some stunning discoveries were made about reasoning and decision making and Cognitive Science and Economics delved to investigate jointly on the neural bases of decision making in both pathological cases and normal subjects – thus flagging off a whole new domain; 'Neuro-economics'.

2.3. Newer working areas

The last 2 – 3 decades saw shifts in Cognitive Scientific studies not limited to understanding human consciousness alone but also addressed the phenomenon behind consciousness. Animal cognition became an interesting working-area of the modern Cognitive Science. Much was written about emotion; particularly how it affects cognition, consciousness studies embraced a wide interdisciplinary network attracting participants ranging from poets – physicists to physiologists. Today, Cognitive Science has found a way to be enriched by and in turn influence a range of disciplines. There has been a flurry of books and researches published on an ever-increasing list of topics. Having grown into a multi-faceted domain, Cognitive Science now has its very own set of agreements, disagreements, schisms, theories of partial reconciliation, splits and methodologies. Stemming on the broad shoulder of works done during the 80s and 90s, we are now in a phase of post-classical Cognitive Science. While there have been completely new works in the post classical era, many studies are but classical topics re-vamped under different guises, increasingly moving on to an interdisciplinary study with multi-disciplinarian enquiries. As the names of the contributing disciplines are on a wane, works pursued in memory, perception, representation, development etc. now come under the broad banner of Cognitive Science.

Within a few years, the first of the many centers of cognitive science was started at Harvard, by Jerome Bruner with the initial focus directed at understanding spontaneous reasoning. Its interdisciplinary mix included faculty, research fellows, visitors and people who had so far made substantial contributions to the domain. Referred initially at Harvard as Cognitive Studies, at Carnegie Mellon as Information Processing Psychology and at La Jolla as Cognitive Science, the name didn't matter until 1976 – when the Alfred P Sloan Foundation took an interest on the matter. Christopher Longuet-Higgins in the Lighthill report (1973) mentioned this enterprise as the 'Cognitive Science'. The founding meeting of the Cognitive Science Society and the Cognitive Science Journal was held at the University of California, San Diego, in 1979. In 1972, Hampshire College started the first undergraduate education program in Cognitive Science, led by Neil Stillings while in 1982, with his assistance, Vassar College became the first institution in the world to grant an undergraduate degree in Cognitive Science. In 1986, the first Cognitive Science Department in the world was founded at the University of California, San Diego. Morphing with the scientific and technical advances of the time, Cognitive Science grew with research groups, journals, degree programs and institutions of its own in close correspondence with the march of technology, computational capacity of computers and the chronology of general scientific progress of the time. Three debates still pop everywhere Cognitive Science is pursued – is it Cognitive Science or Cognitive Sciences, is it an interdisciplinary, multidisciplinary or a transdisciplinary domain and though the central tenet is the same, there is no unanimous one definition for the science.

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References

1. McCulloch, W.S.& W. H. Pitts (1943). 'A logical calculus of the ideas immanent in nervous activity'*. Bulletin of Mathematical Biology 5*, pp. 115 – 133.
2. Rosenblueth, A., N. Weiner, & J. Bigelow (1943). 'Behavior, purpose and Teleology'. *Philosophy of Science 10*, pp. 18 – 24.
3. Lorente de Nó, R. (1938). 'Analysis of the Activity of the chains of Internuncial Neurons'. *Journal of Neurophysiology 1*, pp.207 – 244.
4. Heims, S.J. (1991). The Cybernetics Group, The MIT Press, Cambridge, MA.
5. Dupuy, J.P. (2000). The Mechanization of the Mind: On the Origins of Cognitive Science. Princeton, NJ: Princeton University Press. Translated by M.B. DeBevoise (1994) from *"Aux Origines des Sciences Cognitives"*, La Découverte, Paris.
6. Miller, G.A. 'The Cognitive Revolution: A Historical Perspective' in *Trends in Cognitive Sciences*, Vol.7, No.3, March 2003, pp 141 – 144.
7. Wildgen, W. (2001). 'Kurt Lewin and the Rise of Cognitive Science', in Albertazzi, L. (ed). The Dawn of Cognitive Science: Early European Contributors, Kluwer Academic, Dordrecht, Holland, pp.299 - 332.
8. Rochester, N., et.al. (1956). 'Tests on a cell assembly theory of the action of the brain, using a large digital computer'. *IRE Transactions on the Information Theory 2*, pp. 80 – 93.
9. Bruner, J. R, et.al. (1956). A study of thinking, Wiley, New York.
10. Miller, G.A. (1956). 'The Magical Number seven, plus or minus two'. *Psychology Review*; 63, pp. 81 – 97.
11. Samuel, A.L. (1959). *'Some studies in Machine Learning using the game of Checkers.'* IBM Journal of Research and Development 3, pp. 210 – 229.
12. Jasper, H.H. & G.D. Smirmov (ed.). (1960*). 'The Moscow colloquium in Electroencephalography of Higher Nervous Activity'*. The international Journal of Electroencephalography and Clinical Neurophysiology, Supplement No. 13.
13. Boller, F. (1998). *History of International Neuropsychological Symposium: A reflection of the evolution of a discipline*. Neuropsychologia 37, pp. 17 – 26.
14. Premack, D. (1986). Gavagai! Or the future history of animal language Controversy, Bradford Books/MIT Press, Cambridge, MA
15. Terrace, H.S, et.al. (1979*). 'Can an Ape create a Sentence?'* Science 206, pp. 891 – 902.
16. Karmiloff Smith, A. (1993). *Beyond Modularity: A developmental Perspective on Cognitive Science.* European Journal of Disorders of Communication 28, pp. 95 - 105.
17. Karmiloff Smith, A (1994). *Précis of Beyond Modularity: A developmental perspective on Cognitive Science*, Behavioral and Brain Sciences 17, pp. 693 – 745.
18. Higginbotham, J.T. (1982). *Noam Chomsky's Linguistic Theory.* Social Research 49 (1), pp. 143 – 157.
19. Gazzaniga, M.S. (2000). The new Cognitive Neurosciences (2nd ed.) A Bradford Book/The MIT Press. Cambridge, MA.
20. Posner, M.I (ed.) (1989). Foundations of Cognitive Science. Bradford Books/ The MIT Press, Cambridge, MA.
21. Wilson, R.A. & F.C. Keil (ed.) (2000). The MIT Encyclopedia of the Cognitive Science. Cambridge, MA: The MIT Press.
22. Massimo Piattelli-Palmarini and Lynn Nadel (ed.) (2003). Encyclopedia of Cognitive Science, Macmillan,.

