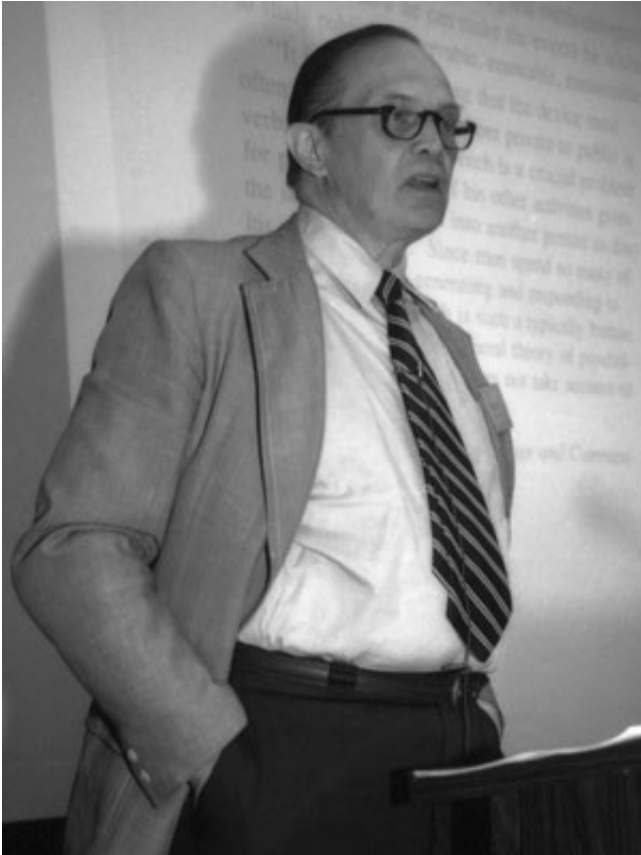# Remembering George A. Miller

September 26, 2012

George A. Miller delivers the Keynote Address, "The Place of Language in Scientific Psychology," at the first APS Annual Convention in 1989.

The human mind works a lot like a computer: It collects, saves, modifies, and retrieves information. **George A. Miller**, *one of the founders of cognitive psychology, was a pioneer who recognized that the human mind can be understood using an information-processing model. His insights helped move psychological research beyond behaviorist methods that dominated the field through the 1950s. In 1991, he was awarded the National Medal of Science for his significant contributions to our understanding of the human mind.*

Miller, who passed away on July 22, 2012, was also a leader in the study of short-term memory and linguistics. In the Keynote Address that he delivered at the first APS Annual Convention in 1989, Miller said that language must be a key element of any theory of psychology because it is a means of making private or internal psychological phenomena observable, measurable, and public. His linguistic work continues to endure through WordNet, *a publicly available lexical database of the English language, which has been applied to the development of search engines and translating programs.*

The 1956 paper "The Magical Number Seven, Plus or Minus Two" is Miller's most famous, and remains one of the most frequently cited papers in the history of psychology. In this classic of cognitive psychology, Miller proposed that short-term memory is subject to certain limits, including span and the quantity of information that can be stored at a given time.

As these remembrances demonstrate, Miller was not only a gifted scientist, but also an extraordinary human being, and he will undoubtedly be an inspiration for years to come.

John T. Bruer

James S. McDonnell Foundation

George Miller taught me how to make hollandaise. In the mid-1970s, George was a professor at Rockefeller University, where I was a graduate student in philosophy. George lived in Princeton, but had an apartment in RU's faculty and student housing building where he stayed during the week. As a graduate student, I was always hungry and looking for a meal. George invited me to dinner at his place. He served nice wine, steak, and asparagus with hollandaise.

Of course, I learned much more from George. I was a philosopher of science, blinded by physics. The philosophers were on the 16th floor of the Tower Building, and the psychologists were on the 4th, with many varieties of (mostly) biologists populating the intervening floors. A number of philosophy students sought out kindred spirits among the psychologists. From being around George and his research group, I acquired an understanding of, and admiration for, cognitive psychology, and I soon came to appreciate that the theoretical and methodological issues surrounding psychological science were every bit as compelling as those arising from physics. It was also around this time, I was to learn later, that George and Mike Gazzaniga, over martinis in the Rockefeller Faculty Club, coined the term *cognitive neuroscience* to describe a new research front in which methods of cognitive psychology and systems neuroscience might interact to place constraints on theorizing in both fields.

In 1986, when I became President of the James S. McDonnell Foundation, I had the opportunity to act on some of what I had learned from George. (No, not the hollandaise!) The McDonnell Foundation Board approved initial steps to establish a research program in cognitive neuroscience. The Foundation turned to George (who at that time was the James S. McDonnell Professor of Psychology at Princeton) to help organize this new effort. At an initial planning meeting, chaired by George and attended by Gazzaniga, Mike Posner, Marc Raichle, and Steve Hillyard (among others), the group advised the Foundation to fund a Summer Institute in Cognitive Neuroscience and to establish five study panels to encourage dialogue between neuroscientists and cognitive psychologists. The goal of the study panels was to outline a research program the Foundation might fund. The five study panel topics were memory, emotion, higher cognitive skills, action systems, and attention. Eighteen months later, we had program guidelines and had enlisted the Pew Charitable Trusts as a collaborator in funding the research. George chaired the program and administered it out of Princeton. Through his efforts and the efforts of those he enlisted, the McDonnell-Pew Program in Cognitive Neuroscience became known as an effective program that had high scientific standards and played a significant role in advancing the research George and Mike had speculated about years before.

George continued in his advisory role to the Foundation for the next 25 years. If it had not been for the

hollandaise, I may not have come to know George, learned to appreciate the psychological sciences, and continued to benefit personally and professionally from his counsel.

Jerome Bruner

New York University

Back in the early 1960s, the "psychotropes" and "sociotropes" were split into two departments at Harvard: Psychology and Social Relations. George was officially in the former, and me, I was in the latter. We two decided that, despite our differences, we'd teach a course together. "Let's list it under Psych," said George, "they need a nudge more than SocRel!" Thus began Psych 148, "Cognition." Some now say it was what kicked off the "cognitive revolution." We had a ball, and we typically dedicated 10 minutes per lecture for student questions. "Let's see what these students make of all this," George proposed. We also invited not only noted colleagues to give guest lectures, but also visitors like distinguished art-historian Ernst Gombrich, who discussed how great painters came to see the world the way they did.

Then the Dean of Arts and Sciences proposed that we give a yearlong general education course on the same range of topics. Both of us froze up a bit. "Gen Ed, my God, can we do *that*?" George wondered. Anyway, we did, and thus began Soc.Sci.8. If I recall correctly, it was called something like "On Knowing," and it dealt with the interaction of individual and cultural factors that were at work when humans come to know and operate in their world. We covered everybody from Wilhelm Wundt to Bronislaw Malinowski, dealing with topics that ranged from how we perceive to how we imagine. George's lectures were absolutely brilliant and also wonderfully self-searching. How I loved that course!

And we goaded a whole generation of teaching fellows to join us as the number of students grew and grew into the hundreds. Indeed, in our last year of teaching Soc.Sci.8, the *Harvard Crimson* chose it as one of the five best courses at Harvard University! Small wonder, for there was something about that topic and that period in the 1960s that brought out a new sense of daring in psychology — and in the new generation.

What a delight it was, dramatizing the contrapuntal in the human condition, and doing it jointly with the remarkable George Miller.

George A. Miller, pictured here with the 1958–59 class of Fellows at the Center for Advanced Study in

the Behavioral Sciences, where he worked on his classic book Plans and the Structure of Behavior. Photo courtesy of the Center for Advanced Study in the Behavioral Sciences at Stanford University Archives

Michael Cole

University of California, San Diego

George was my colleague for nine years at Rockefeller University. We had neighboring apartments. We also shared a research facility outfitted with a lot of expensive audio and video recording devices, which was rare in the 1970s. It allowed us to record a variety of more or less free-flowing, multi-person activities in great detail. It was a facility for studying what now is called embodied cognition.

George and Bill Estes, my thesis advisor, both had laboratories within the behavioral science group at Rockefeller, which included Floyd Ratliff, Neal Miller, Don Griffin, Carl Pfaffmann, and a number of other outstanding biobehavioral scientists. Through a process I have never fully understood, I was hired to become a part of the behavioral-science group.

George wrote about our joint laboratory venture in his book *Spontaneous Apprentices*. The work itself was carried out at a time when Philip Johnson-Laird was a visitor in George's lab, if I recall it correctly. It was here that research on dropping pseudowords into toddlers' conversation and tracking the earliest formations of word meaning was developed. My work in the same facility was focused on the problems of ecological validity that arose in connection with my work on culture and cognition. The facility made it possible to pursue our shared interest in the analysis of early cognitive/language development in relatively unconstrained "everyday" activities.

George and I had such different modes of thinking about psychology that talking to him was like talking across planets. I could never understand the motivations behind or the payoff from the formalisms he sought to develop, but I loved the examples with which he chose to illustrate principles. He, on the other hand, seemed to accept my learning disability vis-a-vis formalization and took my efforts to figure out methodologically appropriate ways to make cross-cultural inferences about cultural variations in psychological test performance seriously. He wrote the preface to one of our early books on culture and cognition, in which he argued that if we were to understand how people acquire cognitive strategies and the knowledge of when to use them, we faced an impossible task if we did not take account of the culture in which they lived.

George was also curious about how we carried out our work beyond the walls of the university. Once he said he would like to come along with me on one of my trips. "Of course," I said — it would be great, if he was serious. When he assured me he was, I invited him to go with me on a trip, and we agreed to arrange it. At the time, one of our research groups was in the middle of a number of studies on the role of schooling in the development of cognitive performance on the Yucatan Peninsula (during the pre-Cancun days). But I was also in the middle of a study of language use in and out of preschool classrooms in Central Harlem.

George thought that I was inviting him to come up to Harlem with me to check out what we were doing

there. But when he found out I was talking about the Yucatan, he scarcely skipped a beat. "Okay, let's go to Mexico." And we did. George worried a little about color perception and the Mayan lexicon, but mostly enjoyed our bizarre mode of life, which included traveling in a small Volkswagen convertible with its top down and George's long legs scrunched up in the passenger seat. He had a hell of a time sleeping in a hammock. But he seemed to enjoy taking in an exotic environment to think about language, culture, and cognition.

The Rockefeller situation was unique. It allowed unbelievable freedom of well-supported inquiry and unlikely coalitions and confluences of people and ideas. It allowed me to share a laboratory, seminar time, and a beer or two with George, which was the pleasure of a professional lifetime.

Alice F. Healy

University of Colorado Boulder

I was one of the few graduate students at Rockefeller when George Miller and Bill Estes both had labs there. I started in George's lab but moved to Bill's lab when George went on leave to the Institute for Advanced Study in Princeton.

The first experiment I published with George was a one-page article in *Psychonomic Science* titled "The Verb as the Main Determinant of Sentence Meaning" (Healy & Miller, 1970). I used George's method of sorting with simple active sentences and showed that when asked to sort the sentences into piles on the basis of similarity of meaning, subjects were more likely to sort them into piles that shared the same verb than into piles that shared the same agent. When I finished the draft of the manuscript, I gave it to George, and he made essentially no changes in it except for the addition of a single sentence at the end: "To use a theatrical metaphor, the main verb of a sentence defines the plot; the subject merely indicates one of the actors." I was delighted to see that this article was cited a fair number of times, including in Henry Gleitman's introductory psychology book *Basic Psychology*. However, rather than summarizing my elegant experimental design or my clear-cut results, almost everyone cites only the last sentence of the article, the one written by George.

George certainly had a way with words and, as others have said, he was extremely astute and insightful. Although he was indeed humble and modest, I went away from each meeting with him feeling confident and uplifted.

Michael Gazzaniga

University of California, Santa Barbara

The following story comes from an essay on George Miller that I wrote for his Festschrift. [1] *George remains very much alive in my mind.*

They used to say that Jack Benny, the world's funniest man, was also the best audience. Everyone loved to try his stuff out on Jack. If George Miller is in an audience, he is usually asleep. If he *is* the audience — that is, if you are one on one — he is the best. He analyzes constantly as you pour out your story. He asks

probing questions, and then as you hear your own answers, and as those silly formulations bounce off his deadpan expression, you begin revising them. There is not much that is new in this world, and certainly not much that is new about the psychological nature of human beings. What passes for discovery these days tends to be an individual scientist's rediscovery and re-terming of some well-established phenomenon. Most of these "discoveries" are soon forgotten, but George knows all of them. So, on the hundredth trip to the well, you are overjoyed to see a glimmer in his eye and to realize that perhaps there was something to your last idea.

We started exchanging stories, mine about episodes in the clinic and his about new experimental strategies. I would tell him about patients with high verbal IQs who lacked a grammar-school child's ability to solve simple problems. He would tell me that psychologists do not yet have anything resembling a theory of intelligence or mind. He urged the continued collection of dissociations in cognition, as seen in the clinic, in the hope that a theory would emerge from these seemingly bizarre and scattered observations.

I took him on my rounds one day and showed him a range of phenomena that ranged from perceptual disorders to language disorders. He had never seen anything like it and commented afterward that the neurologic patient was really what many psychologists were looking for. After all, he observed, psychologists try to test the brain's limits by making college sophomores work fast or by presenting stimuli rapidly to provoke errors. In the clinic, the errors pour out of generally functioning systems with little or no effort.

One patient we saw was a distinguished New York executive who had fallen down a staircase. He was reported to be globally aphasic, which means that he would not understand much, if anything, and would speak only a little. When we arrived in his room, the computer tomography technicians were fetching him for a scan, so George and I tagged along. The technician asked Mr. C. to slide over to the gurney, to which he replied, "Yes, sir." Once positioned and rolling down the hallway to the scanner, he was asked about his comfort. "Are you feeling okay?" "Yes, sir," said Mr. C. After arriving at the scanner, the technician slid the patient off the gurney onto the table and again asked if he felt all right. "Yes, sir," said Mr. C. The scan was performed and Mr. C. was returned to his room. The technician, who was familiar with my studies, turned to me and asked why we were interested in this patient, as he felt there was nothing wrong with him. I turned to the patient and said, "Mr. C., are you the king of Siam?" "Yes, sir," he replied with great assuredness. George grinned and observed that success is always grounded in simply asking the right question.

William Hirst

New School for Social Research

George possessed an extraordinary capacity to reach out to people, embrace new ideas, and make connections outside his own disciplinary domain. Fortunately, along with many others, I benefited from his largesse. Although I was interested in memory, not psycholinguistics, I met George because I was pursuing a postdoctoral fellowship. George was a tall, imposing figure, and I remember sitting in his cavernous, book-filled office, completely intimidated. George quickly put me at ease, and soon said, despite our different interests, "Sure, come and join us. It will be fun."

And it was. George's ability to form close relationships with others led to a constant stream of visitors to his lab, including Tom Bever, Susan Carey, Jerry Bruner, Phil Johnson-Laird, Roy Pea, and Ed Smith. Witnessing this lively atmosphere, two things struck me: how closely connected the visitors felt to George, and the diversity of their interests.

This latter observation underscores George's ability not only to reach out to people, but to do so across disciplines. Before Rockefeller, he introduced information theory, transformational grammar, and many other topics to psychology. He also established the Center for Cognitive Studies, which was the training ground for many first-generation cognitive psychologists.

When I arrived at Rockefeller, George was deeply engaged with Eric Wanner at the Sloan Foundation, holding meetings, writing white papers, and putting the finishing touches on the emergent field of cognitive science. Nowadays, it seems as if the field of cognitive science always existed, but, in large part, it was through George's interdisciplinary reach that it became an established field.

When Mike Gazzaniga moved to Weill Cornell Medical College, which is physically adjacent to Rockefeller, he and George organized a joint seminar on the possibility of bringing together cognitive science and neuroscience. George rightly saw that the time was ripe. With the help of John Bruer of the McDonnell Foundation, George and Mike went on to design a series of workshops aimed at forming the new field of cognitive neuroscience, eventually establishing the Summer Institute in Cognitive Neuroscience, the *Journal of Cognitive Neuroscience*, and the Cognitive Neuroscience Society.

Why was George successful at establishing such a range of personal and intellectual connections? Two words loom large for me: openness and modesty. I saw George's openness at work as I sat at a bar with him, Mike Gazzaniga, and, if memory serves me right, Mike Posner. Clearly not very prescient, I openly wondered if anything meaningful would be learned from brain imagery. Although he was uncertain, George said it would be wrong to shut down such an effort before trying hard.

As for modesty, George once opined that he never wanted to flat-out nix a student's idea or project. Whereas he might privately have reservations, he feared that his dissent could squash an idea that time might reveal as groundbreaking.

Modesty and openness — the two qualities that allowed George to form lasting personal connections, reach across disciplinary boundaries, and foster new ways of practicing psychology. We are all grateful.

P. N. Johnson-Laird

Princeton University

George Miller was one of the founders of cognitive science. In 1942, he went to Harvard in the heyday of behaviorism, but he defied its ban on studying the mind. He investigated the intelligibility of speech sounds in noise. This topic inspired his attempt to apply the recent theory of information to psychology. But he discovered that its measure was of limited value: Semantics mattered more than statistical improbability. It came not in bits, but in meaningful chunks. He put these thoughts into his classic paper, "The Magical Number Seven, Plus or Minus Two." It exemplifies two of his outstanding abilities: He could think more deeply than others, and he could put his thoughts into beautiful, transparent prose. His

1960 book with Galanter and Pribram, *Plans and the Structure of Behavior,* replaced the behaviorist's conditioned reflex with feedback loops, which could be embedded within themselves recursively. It was said that Miller wrote the book, Galanter read it, and Pribram believed it. That same year, the cognitive revolution came of age when Miller set up the Harvard Center for Cognitive Studies with Jerome Bruner. His interest in communication led to a collaboration with Chomsky, and to pioneering experiments investigating syntax. Once again, however, meaning mattered. And from this point on, he devoted the rest of his life to research into semantics. He set up a laboratory at Rockefeller University to study how children acquire the meanings of words — a project that resulted in his book *Spontaneous Apprentices: Children and Language,* a study in developmental psycholinguistics. This research led to theoretical investigations of the mental dictionary and to Miller's final project, which lasted almost until his death. This was the development of *WordNet*, a large-scale computerized dictionary-cum-thesaurus that represents the semantic relations among words. It was developed at Princeton with Christiane Fellbaum and others. The project was a success. *WordNet* is by far the most widely exploited lexical database used in search engines and in research in computational linguistics.

Miller had a formidable intellect, and for those of us who worked with him, he led by example rather than instruction. He took our drafts and, as he would say, put them through his typewriter, and they would emerge magically transformed — original, profound, and lucid. His lectures and colloquia were impeccably prepared and delivered. They inspired many of his listeners to become cognitive scientists. Miller received many honors, including the National Medal of Science in 1991. And, as long as scientists study the mind, they will honor ideas that he was the first to formulate.

Valerie F. Reyna

Cornell University

I was George's last student at Rockefeller University and his first at Princeton. One joined a laboratory at Rockefeller, not a department, where each professor "was a department unto himself." I will forever be grateful to George and to Bill Estes for welcoming me into that intellectual paradise. Unlike in so many ways, Bill pursued a problem over decades, but George had a habit of starting things. He helped start whole fields, such as cognitive psychology, psycholinguistics, and cognitive neuroscience. He was incredibly brilliant, but worse than that, he was among the finest writers science has produced—all pretty daunting for a student. My only consolation was that he confided that his mellifluous phrases were the result of revision. These phrases still ring in my ear, and offer a historical tour of psychology: In 1956, he wrote the much-cited paper, "The Magical Number Seven, Plus or Minus Two," describing human information-processing capacity. The paper begins dramatically, "My problem is that I have been persecuted by an integer." The number seven continued to follow him, appearing as the number of chapters in his books, among other "coincidences." President of that other psychological organization from 1968–1969, he urged us to "give psychology away," which has echoed and inspired ever since. Describing the serial-position effect, he once said to me, "The mind sags in the middle," a more interesting description than this effect deserved. Children were "spontaneous apprentices" who did not need to be taught language, but learned it nevertheless. The latter work in psycholinguistics probably influenced me most, enshrined in the verbatim-gist distinction in fuzzy-trace theory.

Roger N. Shepard

Stanford University

My first exposure to George was during my 1951–1955 graduate studies at Yale. The two psychology colloquia that I found the most stimulating and influential at Yale were both given by George. One was on his soon-to-be famous "The Magic Number Seven, Plus or Minus Two," which he presented without notes, and with all the elegance and dramatic flare of a professional actor. It was almost as if he had delivered his entire article from memory. His other colloquium presentation was on his *tour de force* study, with Patricia Nicely, on frequencies of auditory confusions among 16 consonant phonemes under many different conditions of noise and filtering.

After I finished my dissertation, George invited me to join him at Harvard as a postdoctoral fellow. This was an exciting time to be in the Cambridge area. There were many promising young researchers in the area who were beginning to advance psychological science in new directions. Several of us regularly met at MIT in an informal evening group known as "The Pretzel Twist." I shared an office/lab with Dick Neisser that was adjacent to George's office in the basement of Harvard's Memorial Hall. I remember when George's first submission to *Scientific American* was accepted for publication, George (half jokingly) told me this was part of his ongoing "MMF" plan — to "Make Miller Famous"!

George continued to play a significant role for me while I was a member of the technical staff at the Bell Telephone Laboratories. Inspired by a workshop hosted by Allen Newell and Herbert Simon, I thought of using Bell's facilities for computer simulation of cognitive processes of perceptual learning. But when I mentioned artificial intelligence to the executive director, he exclaimed, "Ah yes, AI. There is no holding that area up; it keeps hitting new lows!" Ultimately, I arranged a series of visits to the Labs by George Miller, Noam Chomsky, and Marvin Minsky. The visits of the Chomsky-Minsky-Miller triumvirate stimulated an unusual amount of interest, discussion, and controversy at Bell.

I left Bell Labs after both George and his Harvard colleague Dick Herrnstein approached me about returning to Harvard. The prospect was thrilling, but also daunting. Although this time I would be a full professor, I had never before taught in a classroom, nor had I kept up with the substantive developments in psychology occurring in academic departments. After my move back to Harvard, as I was anxiously on my way to deliver my first lecture, I encountered George in the parking lot. He asked what I was rushing off to. Striving to mask my trepidation, I replied that I was about to give my first lecture. "Oh yes," said George, "but do remember, you are now at Harvard. No matter what you lecture about, there will always be some students in the audience who know more about the subject than you do!"

I was always in awe of George's mental quickness, the cleverness of his verbal skills, and the wonderful examples he used to illustrate his points. I remember how he enjoyed wordplay, as when he described a problem as being solved "in one fell swoop … or full sweep," or used "The good can decay many ways" versus "The good candy came anyways" as an example to illustrate how the same vocalization could have two totally different interpretations and how the interpretation determined where the continuous sound stream was perceptually broken into distinct words. I believe George's unsurpassed effectiveness as a speaker stemmed from his natural talent for acting. I fondly recall a Greek tragedy performed in the open air on a grass field in the Five Fields community where the Millers lived. I believe that both George and his wife, Kitty, performed in that tragedy with George providing a spoken commentary, perhaps in lieu of a Greek chorus.

On learning of George's death and beginning to face my own mortality, I am especially regretful that I never told George how much his example and his mentorship benefited me throughout my career. I will miss him.

Eric Wanner

Russell Sage Foundation

I can't quite remember how long it took me to get over my fear of George, but it must have been some years after graduate school, and even then, as the anxiety receded, it left behind a powerful blend of intellectual awe and respect that prompted me to urgently summon my "A-game" whenever we got into anything more than a casual conversation. George's thinking was so clear and precise. He knew so much that I wanted to learn. And he wrote such lean, elegant prose. It was impossible not to aspire to be like him, but equally impossible to imagine actually fulfilling that aspiration.

Jerry Bruner and George famously teamed up to found the Center for Cognitive Studies at Harvard in the early 1960s. For those graduate students who gravitated to the Center, it was a heady time. Throwing off the philosophical constraints of behaviorism, and facing up to the scientific problems of building and testing theories of the mental processes underlying intelligent behavior — these were the challenges that made us all feel we were about to create a new and more successful kind of psychology. If Jerry Bruner was the inspirational leader who made us feel that all things were possible, George Miller was the intellectual grown-up who made us realize that formulating explicit, testable theories of the mind was not child's play. He was the first person who introduced us to computation as a metaphor for mind. In this introduction, he was aided and abetted by an actual computer (a PDP 4 with all of 8K of random access memory) and an abstract one — a cardboard mock-up of a universal Turing machine.

Of the two, it was the abstract computer that had by far the bigger impact on me. The theory of automata was a revelation. George Miller is famous in psychology for his widely read publications, but for me, his most influential work consisted of the three obscure chapters he wrote with Noam Chomsky for the *Handbook of Mathematical Psychology* in 1963. In 200 dense and difficult pages, Chomsky and Miller introduced the formal analysis of natural language and described the hierarchy of automata required to process languages with ascending degrees of formal complexity. The chapters provided a clear theoretical framework for psycholinguistic research on language processing — a way to model the mental gymnastics that go on unconsciously as we understand and produce sentences. I remember reading the *Handbook* chapters at a rate of about five pages a day. It all took a while to sink in, but when it did, it changed my life.

George left Harvard for Rockefeller University in 1967, so he was never officially my thesis advisor. But in a deeper sense, I was certainly always his student. We stayed in touch, and in the mid-1970s, he found a way for me to visit his lab at Rockefeller on a monthly basis while I finished testing the psychological significance of an augmented transition model of syntactic processing — one of the beasts in the jungle of automata George had envisioned. I vividly remember one afternoon when George and Morris Halle gave me three full hours of undivided attention to explain the model and the experimental results supporting it. [2] I've never had more pure intellectual fun before or since. And for once, George wasn't all that scary, either.

Footnotes

[1] Published in The Making of Cognitive Science: Essays in Honor of George A. Miller, by W. Hirst (Ed.), 1988, New York, NY: Cambridge. [Return to Text](#)

[2] Linguistic Theory and Psychological Reality*, by M. Halle, J. Bresnan, and G.A. Miller (Eds.), 1981, Cambridge, MA: MIT Press.* [Return to text](#)