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JOSEPH CARL ROBNETT LICKLIDER

1915—1990

A Biographical Memoir by

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Biographical Memoir

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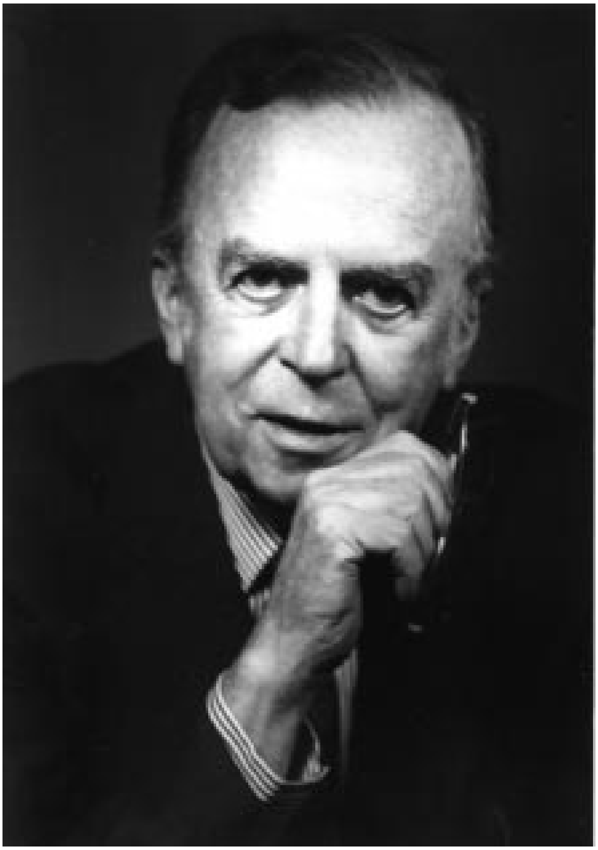

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JOSEPH CARL ROBNETT LICKLIDER

March 11, 1915–June 26, 1990

BY ROBERT M. FANO

JOSEPH CARL ROBNETT LICKLIDER was known as Lick to family, friends, colleagues, and almost everybody else; I will refer to him informally as Lick, as he would have wanted. At the time of his death he was a member of the Engineering Section of the National Academy of Sciences, elected in 1969, and a professor emeritus of computer science in the Department of Electrical Engineering and Computer Science, and a member of the Laboratory for Computer Science of the Massachusetts Institute of Technology. He was an imaginative experimenter and theoretician, an intellectual leader, and a visionary, who left major marks in two distinct fields: psychoacoustics and computer science.

Lick was born on March 11, 1915, in St. Louis, Missouri, the only son of Joseph Parron Licklider, a Baptist minister, and Margaret Robnett Licklider. He graduated from Washington University in St. Louis with majors in psychology, mathematics, and physics in 1937, and was awarded an M.A. degree in psychology the following year. He continued his graduate studies in psychology at the University of Rochester, where he received a Ph.D. degree in 1942.

Lick's Ph.D. research at the University of Rochester was an experimental investigation of the "place" and "frequency of neural impulses" theories about the perception of pitch and loudness. Specifically, he measured the magnitude, frequency, and loci of cortical electro-neural activity in the brain of animals in response to tones presented to the ear.[1,2] Lick must have completed this research and other degree requirements in 1941, because he accepted a research associate appointment at Swarthmore for the 1941-42 academic year to work on a related research topic; however, his stay at Swarthmore was cut short by World War II. Lick never returned to the type of pioneering neuroscience research of his thesis.

Lick's professional career began at Harvard University in 1942 with his appointment as research associate and later on as research fellow in the Psycho-Acoustic Laboratory. It was wartime and the laboratory was involved in research for the military services. A major concern was radio communication with aircraft, which was rather poor because of signal distortion and additive noise from various sources. Lick proceeded to investigate the intelligibility of speech distorted in all sorts of ways, and in the presence of various types of additive noise. In the words of Walter Rosenblith,[3] "There is hardly any size or shape of Procrustus bed on which Lick has not stretched, clipped, tilted or even differentiated speech before listening to it." The massive amount of experimental work he carried out required a similarly massive amount of electronic equipment. Electronic technology was still rather primitive at that time and it took a great deal of ingenuity and skills to design, build, and maintain the necessary equipment. It took also the sort of skeptical mind that Lick possessed to make sure that the experimental results were genuine rather than consequences of unintended characteristics of the equipment employed.

Lick's wartime research was presented after the end of the war in a series of papers (1946, 1947, 1948), many of them co-authored with various colleagues of the Harvard Psycho-Acoustic Laboratory. Of particular importance is Lick's discovery that infinite peak clipping of speech waves resulted in a surprisingly small reduction of their intelligibility, and that such reduction could be minimized by differentiating speech waves before clipping them and integrating the resulting rectangular wave forms. Since infinite peak clipping of a wave form preserves only the zero crossings of the wave form (the points where it switches from a negative to a positive value and vice versa), the locations of the zero crossings of speech waves had to contain most of the information necessary to understand speech, a very remarkable conclusion. This discovery led to significant equipment improvements, for which Lick was granted a patent.

Nineteen forty five, the year World War II ended, was a turning point in Lick's personal and professional life. On January 20, 1945, he married Louise Carpenter; their two children Tracy Robnett and Linda Louise were born in 1947 and 1949, respectively. Louise, besides raising the two children, found time to investigate with Lick the hoarding behavior of rats and co-authored a paper on their observations (1950). On the professional side, the end of the war allowed Lick to turn his attention to more basic questions about speech and hearing. The immediate postwar period was also a time of intense interdisciplinary activity in the Cambridge research community, centered on Norbert Wiener's notion of cybernetics, or control and communication in the animal and the machine. Lick became an active member of that community and an assiduous participant in the weekly gatherings led by Wiener. He learned the models and analytical tools of the new statistical communication theory propounded by Wiener, which soon began to pay dividends in his research on hearing.

Lick's postwar research at the Harvard Psycho-Acoustic

Laboratory was centered on binaural hearing in an effort to identify auditory processes that take place in the central nervous system rather than at the periphery. For instance, in the case of speech masked by white noise, he discovered that intelligibility could be increased by as much as 25% by inverting the polarity of the speech signal at one ear relative to that at the other ear (1948). He also studied binaural beats resulting from presenting to the two ears tones of frequencies differing by a small amount, and proposed a neural mechanism that could explain his experimental results (1950).

The Biennial Award for Outstanding Contributions to Acoustics was presented to Lick at the 1950 spring meeting of the Acoustical Society of America.[3] In July of the same year he joined the faculty of the Massachusetts Institute of Technology as an associate professor in the Department of Electrical Engineering and, later on, in the Department of Economics and Social Science. During his stay at MIT (1950-57) he was at various times and concurrently a group leader in the Lincoln Laboratory and a member of the Acoustic Laboratory and the Research Laboratory of Electronics. He was able to attract to MIT a small group of excellent experimental psychologists, including David Green, George Miller and John Swets, presently members of the Psychology Section of the National Academy of Sciences, with the goal of forming a new department, a goal that for various reasons he was unable to achieve.

Lick's publications while at MIT show a radical shift of his research toward the building of theories about sound perception based on existing experimental data, as contrasted with the experimental focus of his previous research. The most important result of this research was his duplex theory of pitch perception published in 1951 and later extended (1956) to a triplex theory covering binaural perception. These theories of perception were based on the notions of auto-correlation and cross-correlation functions propounded by Norbert Wiener and on Lick's clever observation that the operations involved in the computations of such functions (namely, delay, multiplication, and averaging) could be approximately performed in real time by the nervous system. The theory-building effort went hand in hand with critical, detailed reviews of the development and current state of psychoacoustics. Lick contributed two chapters (1951), one co-authored with George Miller, to the *Handbook of Experimental Psychology*, edited by S. S. Stevens. He also contributed the chapter on hearing to the 1953 *Annual Review of Psychology*.

Lick's theory-building effort had an experimental component that is not apparent in his formal publications. However, in a 1988 oral history interview[4] he mentioned having put together a large amount of analog computer equipment: "I used the analog equipment mainly for generating stimuli, collecting responses, analyzing them, and so on. It was having analog computers, and finally learning how to master them, that led me to do modeling on them." He found out, however, that analog computers were not flexible enough to help him in his theory-building effort:[4] "I had a big analog computer lab, because I was modeling brain stuff, and I realized that I could not do what I was trying to do with analog computing." This disappointment with analog computers marks the beginning of his love affair with digital computers as modeling tools.

Psychoacoustics research was only a part of Lick's activities at MIT. In addition to his academic duties, he participated in Project Hartwell on undersea warfare and in Project Charles on air defense. The latter led to the formation of the Lincoln Laboratory where he became leader of the psychology group. Lincoln Laboratory started in a renovated

World War II building on the MIT campus and moved to its present suburban location a couple of years later. George Miller, who had become co-leader of the psychology group, moved to the new location, while Lick remained on campus. The decision on who would move was reached by flipping a coin, and according to Lick,[4] both thought they had lost.

Lincoln Laboratory's task was to develop a new type of air defense system using digital computers to analyze the information provided by several radars, identify the locations of enemy bombers, and provide control information for interception of fighters. There was plenty of work for experimental psychologists, because there had to be human links in the overall process (namely, flight controllers, who would look at the tracts of enemy bombers and give directions to the individual fighters). The experimental demonstration system used the Whirlwind computer, which recently had been completed under the direction of Jay Forrester. The man-machine interfaces consisted of large cathode ray tubes on which the processed radar information was displayed and of light guns or pens that could be used to specify to the computer particular locations on the image displayed. Thus, Lick's first close encounter with a powerful digital computer was with one with a visual display and a capability for real-time, man-machine interaction. Later on, he rubbed shoulders at Lincoln Laboratory with Wes Clark, who invited him to use the TX2 computer, which had just been completed. The TX2 was a powerful, transistorized computer with a visual display and light pen that Clark had designed specifically for man-machine interaction. No wonder Lick, as an experimental psychologist, fell in love with digital computers.

By 1957 George Miller had left MIT for a professorship at Harvard, and Lick's psychology group at MIT was beginning to fall apart. Lick concluded that he could not do what he wanted to do, including learning how to use digital computers while trying to build a psychology department.[4] He joined Bolt Beranek and Newman, Inc. (BBN) as a vice-president and head of the departments of psychoacoustics, engineering psychology, and information systems research. BBN at the time was a relatively small acoustic consulting firm, and the three founders were MIT professors in the departments of physics, electrical engineering, and architecture. BBN was trying to expand its activities and agreed to purchase a small computer for Lick. The computer, a Librascope LGP-30, turned out to be inadequate and error prone, but Lick learned to program on it.

Fortunately for Lick, Digital Equipment Corporation, founded in 1957 by Ken Olsen and Norm Andersen to build digital components, decided in 1958 to produce a small transistorized computer, the PDP-1, similar to the TX0 computer on which the two founders had worked at Lincoln Laboratory. The TX0 computer was a smaller predecessor of the TX2 and, like the TX2, it had a visual display and light pen and was intended for online use. The first PDP-1 computer was delivered to BBN in 1959. It was just what Lick needed, and he quickly became addicted to it. But, something still was missing to complete Lick's metamorphosis: a group of bright computer people with whom to interact.

By then the TX0 computer, no longer needed at Lincoln Laboratory, had been moved to the MIT campus into the Research Laboratory of Electronics for use by faculty and students. Not long thereafter, the TX0 was joined by a PDP-1 computer donated by DEC to the Electrical Engineering Department. The new computer laboratory, more accessible and informal than the MIT Computation Center, became a Mecca for faculty and graduate students, and a new computer community grew around it. Lick, who was still at home on the MIT campus, found there a congenial group to interact with, and a source of talented consultants and part-time help for his work at BBN. Thus, Lick became an active member of the computer community.

Psychology and computers happily cohabited and supported each other in Lick's nimble mind throughout his five-year stay at BBN. Computer modeling played a major role in his psychology publications, and a psychologist's point of view and interest in the workings of the human mind was evident in his computer publications of that period.

While at BBN, Lick published several psychoacoustic papers. Three of them deal with an entirely new topic: the use of sound to suppress pain in dental operations. The procedure, developed by Dr. Wallace J. Gardner, a dentist, consisted of playing music in the earphones of the patient, followed by white noise at the onset of pain, with the sound volume and the switching from music to noise under control of the patient. Dr. Gardner and several other dentists fount it to be very effective for most patients. The last of the three papers is of special interest because it displays Lick's views on the purpose of computer models and the intellectual importance of the modeling process itself. These views are important to understanding the origin and rationale of Lick's vision of man-machine symbiosis and of his later crusade to bring about its realization.

Lick pointed out in the introduction of his paper (1961) entitled "On Psychophysiological Models" that the paper was not a written version of the talk he had given at the symposium on sensory communication held earlier at MIT. Apparently, his talk had not been well received, because he had discussed models and modeling in too general terms and many people in the audience had failed to understand the points he had tried to make. So, he decided to present a specific instance of modeling, one in which the experimental evidence was qualitative rather than quantitative, to make the point that useful models could be constructed even in such cases. The paper describes the procedure employed in auditory analgesia and the clinical evidence available about it. Next, it presents a psychophysiological model of the interaction of the auditory stimulus with the pain that results in the suppression of the latter, and then validates the model by comparing its behavior with the clinical evidence.

The last section of the paper makes several important observations. The first one is that a model, while a tentative and oversimplified representation of reality, organizes and interrelates the experimental evidence in a concise way that is easy to understand and remember. The second observation is that one can validate a model by observing its behavior, when simulated on a digital or analog computer, and comparing it with qualitative as well as quantitative evidence. The third point is that a model can be a valuable stepping stone in planning further experiments and in identifying the experimental data to be obtained. The last observation, and here I am somewhat reading between the lines, is that the very process of constructing a model by trial and error provides insight into the relationships between specific structural and behavioral characteristics of the model and, therefore, between structural characteristics of the model and the experimental evidence against which the model has to be validated. Another remark made in the paper worth mentioning for future reference is that the development of an appropriate model proved to be very time consuming, because neither the digital computer nor the analog computer employed were adequate to the task. The digital computer, presumably the PDP-1, was much too slow and the analog computer was too inflexible for studying a variety of models.

Lick published his history-making paper on man-computer symbiosis in March 1960. By then he had learned a great deal about digital computers and programming with the help of a group of brilliant and knowledgeable people he had attracted to BBN as full-time staff and consultants. This newly acquired knowledge—together with his experience and frustration with the process of model building with currently available computational tools—led him to the vision of a future intimate collaboration between man and computer in which each partner would supplement and extend the capabilities of the other. In order to validate the implied assumption that intellectual activities would be significantly facilitated and improved by such an intimate partnership, he conducted a detailed and lengthy analysis of his research activities, similar to an industrial time-and-motion study. He found that some 85% of his research time was devoted to performing routine clerical or mechanical operations ranging from calculating and data plotting to collecting information, tasks that in principle could be performed better and faster by a computer. Of course, appropriate computers and the necessary programs and databases were not available at that time. After describing the vision of man-computer symbiosis and validating its value, the paper outlines in some detail a research program, including its hardware and software requirements. This is indeed the research program that Lick launched in 1962 when he became the first director of the Information Processing Techniques Office (IPTO) of the Advanced Research Projects Agency of the Department of Defense.

A major project on which Lick worked at BBN was a study of future libraries, which was supported by the Council on Library Resources, an organization established by the Ford Foundation in 1956. After lengthy consultations with distinguished leaders from a variety of research organizations, the council had selected Lick to lead the project (1965). It was intended to be a five-year effort beginning in November 1961, but it lasted only two years because Lick left BBN in October 1962 to become director of IPTO, and even his long-distance supervision of the project had to be terminated a year later. The final report on the project, completed in January 1963, was deemed by the council to be an important contribution deserving publication in book form.

The book *Libraries of the Future*, published in 1965, presents a vision of future libraries based on Lick's vision of man-computer symbiosis. The first half of the book is similar in structure to his earlier paper. After limiting the scope of "Libraries" to the body of documents that could be stored in digital form without loss of value and estimating its current size, Lick presents a detailed analysis of the intellectual processes involved in the acquisition, organization, and use of knowledge. This is followed by a description of the structure and usage of the "procognitive systems" he envisioned, capable of searching the body of documents under user control. Finally, Lick outlines, as in his earlier paper, a research program intended to bring about his vision. The second half of the book reports on the initial steps of the research program carried out as part of the library project.

In addition to his work at BBN, Lick served in 1958 as president of the Acoustical Society of America and in 1960 as president of the Society of Engineering Psychologists.

Lick's life took a major turn when he and Fred Frick, whom he knew from his Harvard days, were invited to visit Jack Ruina, director of the Advanced Research Projects Agency (ARPA), who needed somebody to oversee an existing project on Command and Control at the System Development Corporation (SDC) and to respond to a recommendation of the Defense Advisory Board to bring behavioral researchers together into a new institute with better research facilities.[4] Fred Frick, a psychologist by training, was heading at the time the Communications Division of Lincoln Laboratory and was therefore an obvious candidate. Lick had been for several years a member of the U.S. Air Force Scientific Advisory Board and had chaired a special committee on human factors; however, he and Jack Ruina had not met before. As reported by Lick in his 1988 interview,[4] Jack Ruina stressed the importance of the position he was trying to fill and even asked Eugene Fubini, assistant secretary of defense, to give a "sales pitch" to the two candidates. Lick, in turn, gave an eloquent presentation of his vision of man-computer symbiosis, stressing his view that not much progress could be made with Command and Control problems without online man-computer interaction. Apparently, both Fubini and Ruina were impressed by Lick's presentation and agreed with his conclusions about Command and Control. While both candidates were reluctant to leave their present positions, Lick must have seen the opportunity to launch the sort of research program that he had outlined in his 1960 paper. He accepted the position with the understanding that he would be free to launch his research program mainly in university laboratories out of the context of command and control or any other specific military application.

Lick became director of the ARPA Office of Information Processing Techniques and Behavioral Sciences in October 1962. The behavioral sciences part of his charter disappeared very soon because the behavioral scientists for whom the institute had been proposed were not interested in it.[4] Thus, his office became simply the Information Processing Techniques Office, or IPTO for short. Lick lost no time in getting started. He neither mailed out requests for proposals nor waited in his office for proposals to arrive. Rather, he visited many computer research laboratories looking for interesting work and, perhaps even more importantly, for good people; he was a good judge of both. I recall his visit to MIT in mid-October. He spoke with his usual enthusiasm whenever he had a chance about the virtues of man-computer interaction and his excitement proved contagious. He infected me with his enthusiasm so quickly that a tentative agreement with MIT to organize Project MAC, of which I became the first director, was reached in early November, and a formal proposal was on his desk by mid-January 1963. All this happened in spite of the fact that I had neither a prior desire nor prior qualifications to manage a large research program, particularly in the computer field.

The IPTO program[5] initiated by Lick turned out to be very successful, so much so that it has become by now a model for other government-sponsored research programs. There were various reasons for its quick success. The time was ripe for the blossoming of computer science, and the funds available to IPTO, while a small fraction of those available to ARPA and invisible in the Department of Defense budget, were huge in comparison to the resources of other funding agencies. Much of the credit should go to Lick for starting the program on the right track with policies from which his successors did not materially depart. It was structured like no other government research program, akin to a single, widely dispersed research laboratory with a clear overall goal, with Lick acting as its director and intellectual leader. He fostered close communication and collaboration among all parts of his far-flung laboratory, thereby creating what became known as the “ARPA community.” He further instilled in that community the sense of adventure, dedication, and camaraderie that he had learned to value in his research career. He also made sure that the availability of computer resources would not be a limiting factor in the research program, and that plenty of funds would be available for the support of graduate students, whom he correctly regarded as a most important and precious resource.

One of Lick's suggestions with which I am personally familiar proved to be particularly valuable (he encouraged or persuaded people, but never told them what they should do). He suggested that it would be a good idea to start Project MAC with a summer study with participants from major computer research laboratories. There were many meetings and a lot of discussion during the two-month study, with a few memoranda being written. However, no report was ever prepared, because there was no significant new conclusion or recommendation to be presented and, moreover, no formal report was expected. The summer study turned out to be a great "get acquainted party," where participants got to know one another and had the opportunity to become familiar with two large, recently completed time-sharing systems that were available for their individual use: one developed at the MIT Computation Center and the other developed at the System Development Corporation. The study certainly helped to get the IPTO program on its way, and that was just what Lick had in mind.

The IPTO program was initially criticized by a number of leading people in the computer community, and very vociferously by some of them. They believed that online use of computers was wasteful, and therefore, that the whole program constituted a waste of government funds. But, Lick stood his ground, and time proved them wrong. They had missed Lick's main point that computers, although still expensive, could be produced on demand, while creative, competent people could not.

Lick completed his two-year tour of duty at ARPA in 1964; however, he returned to ARPA in 1974 for a year to serve again as director of IPTO at a time when no other suitable person could be found. Unfortunately, that second tour was not as pleasant for him as the first. He had to contend with budgetary pressures resulting from the war in Vietnam and with new justification requirements for the expenditure of research funds. ARPA had become more bureaucratic, and Lick did not feel comfortable in that environment; nevertheless, he did his duty and kept the IPTO program on track.

After his first ARPA tour of duty, Lick went to IBM with the somewhat vague title of consultant to the director of research. Apparently, and not surprisingly at the time, he did not find there a research environment congenial to his views and research interests. He, therefore, made arrangements to return to MIT in 1966 as a visiting professor. The following year he accepted a permanent appointment in the Electrical Engineering Department and from 1968 to 1970 served as director of Project MAC, the research laboratory he had been instrumental in establishing in 1963 and which became eventually the present Laboratory for Computer Science.

Lick was disappointed upon his return to MIT by the lack of progress in two areas that were crucial to his goal of man-computer symbiosis: visual man-computer interfaces and software systems that would facilitate building computer models and exploring their behaviors without writing elaborate programs from scratch. In order to make progress in those areas, he formed a new research group in Project MAC and quickly attracted a large number of students, both graduate and undergraduate. The name chosen for the new group was Dynamic Modeling, indicating its intended research objective.

Lick's goal[6] was a self-contained, coherent, interactive computer system that could be used by researchers with moderate computer skills to investigate the behavior of a variety of models with little programming required on their part. Of course, users were to interact with the computer system mostly through visual displays with light pens or similar input devices. The software scheme conceived by Lick was very different from any existing problem-oriented language. Briefly, it was akin to a software Tinkertoy, based on a vast library of software modules that readily could be assembled into specific models and programs for investigating them. New modules could be constructed and added to the library by users to meet their special requirements, so that the library would eventually become the repository of the work of the community. Also, a descriptor would be attached to each software module to facilitate searching the library for appropriate modules. Both the goal and the implementation scheme were very ambitious, perhaps too ambitious in view of the computers available at the time. Yet, they were not unrealistic, given Lick's faith that computer speeds and memory sizes would increase rapidly in the future while their costs would decrease, as in fact they did.

The implementation effort started in 1969, and Lick personally developed a significant fraction of the library, which grew over time to some 2,000 modules. By 1974 it had turned into a major system development effort in terms of hardware, software, and programming staff.[7] Also, the intended use of the system had been broadened to include general software development and problem solving, and the name of the research group had changed correspondingly to Programming Technology. Apparently, all components of the system had been completed by early 1974,[8] when Lick went back to ARPA for his second tour of duty. Although much work remained to be done to integrate the system and increase its execution speed, the project appears to have ended at that time, as no further mention of it can be found in later Project MAC progress reports. The abrupt ending was probably the result of ARPA's policy of limiting to five years its support of any specific project. Lick returned to MIT in the fall of 1975, but he never wrote any overall report or journal article on the project to which he had devoted so much personal effort. This suggests that Lick may have been disappointed by the outcome of the project or perhaps he had concluded that his goal was beyond the capabilities of the current computer technology. Lick reached his mandatory retirement age in 1985.

Lick was an excellent and, at times, amusing speaker. He was also a gifted and prolific writer; his bibliography lists more than 100 formal publications, in addition to laboratory reports. He was in great demand as a keynote and banquet speaker, as a participant in a variety of symposia, and as a member of military and civilian study committees. In addition to the National Academy of Sciences, he was a member of the American Academy of Arts and Sciences, the New York Academy of Sciences, and the Washington Academy of Sciences, and a fellow or member of a large number of other professional societies. As mentioned above, he was the recipient of the 1950 Biennial Award of the Acoustical Society of America. He was also the recipient of the 1965 Franklin V. Taylor Award of the Society of Engineering Psychologists, of the 1968 Outstanding Alumni Award of Washington University, and of the 1990 Commonwealth Award for Science and Invention. The last, but not the least, recognition of Lick's contributions was a special session in his honor held at the April 1991 meeting of the Acoustical Society of America with invited presentations by his old psychoacoustics colleagues and friends Irwin Pollack, Karl Kryter, George Miller, John Swets, and Reinier Plomp.[8]

It is interesting to note that, while Lick was nominated for membership in the National Academy of Sciences by its Psychology Section, upon his election in 1969 he chose the Engineering Section as his home, having become by then a leading member of the computer science community. Yet, after walking through Lick's career in an attempt to understand the evolution of his intellectual interests and motivations, I came to the conclusion that he was first and foremost a psychologist throughout his professional life. Psychoacoustics was his primary, long-lasting interest and his source of motivation; his very last research project was still motivated by his interest in modeling psychoacoustic phenomena. More broadly, he was interested in almost any aspect of human cognitive activities. While he became a knowledgeable and skillful programmer, his focus remained on the cognitive aspects of computer usage. He was fascinated by computers, because he understood in a deep way their potential to help people in a broad spectrum of activities by extending and amplifying their intellectual power, by improving the effectiveness of their communication and collaboration, and last but not least, by freeing them from the drudgery of clerical operations, to which he was particularly allergic.

Lick's legacy is obvious to anybody old enough to be familiar with the state of computers and their usage in 1960, when he published his famous paper on man-computer symbiosis. His vision, which was science fiction to many at that time, is now a reality and is taken for granted by people around the world. The Internet is the embodiment of the "inter-galactic network" he was talking about with glee as far back as 1963. Libraries are fast approaching the vision described in his book *Libraries of the Future,* and the U.S. Armed Forces have embraced the views on Command and Control eloquently presented in his 1962 ARPA interview.

And all this on top of his very significant contributions to psychoacoustics—quite a legacy indeed. Lick must have been conscious of it, but he was much too reserved and modest to give any sign of his awareness. In closing, I wish to acknowledge my personal debt to Lick; I had the privilege of knowing him as a colleague and friend since 1950, when he first joined the MIT faculty, and the great luck of being exposed at the right time to his ideas and his contagious enthusiasm.

ACKNOWLEDGMENT

I am very grateful to Louise Licklider for loaning me Lick's personal files, including his curriculum vitae, list of publications, and copies of his books and technical papers. This material was my primary source of information, particularly about Lick's contributions to psychoacoustics with which I was only vaguely familiar. Another important source was Lick's interview by Aspray and Norbert,[4] and I am indebted to John Swets for giving me a copy of the interview transcript. The transcript filled some gaps in my memory, and more importantly, provided essential information that I needed to understand the events and the intellectual process that led Lick from psychoacoustics to his vision of man-computer symbiosis and to his formulation of the IPTO research program. I am also indebted to Karl Kryter, Lick's closest friend, best man, and fellow graduate student at Rochester for information about Lick's doctoral research, for suggesting a paragraph about it, and for providing the two references to it that were not included in Lick's publication list. I am similarly indebted to Albert Vezza for helping me understand the scope and character of the research carried out in Lick's group in Project MAC, and Lick's personal contributions to it; he took over the leadership of Lick's group in 1974, when Lick went back to ARPA. Lick's portrait was made by Koby-Antupit Photographers of Cambridge, Massachusetts; I thank them for giving me their permission to use it and I thank Michael Yeates of the MIT Museum for providing a copy of it. Finally, I wish to express my deep gratitude to Peter Elias, Karl Kryter, George Miller, Irwin Pollack, John Swets, and Albert Vezza, all of them Lick's former colleagues and collaborators, who reviewed my manuscript. Since I undertook to write this memoir with a great deal of trepidation about my ability to write a correct, coherent, and meaningful account of Lick's diverse career and contributions, their kind expressions of approval were very much appreciated.

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