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CLARENCE HENRY GRAHAM

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A Biographical Memoir by

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CLARENCE H. GRAHAM was an experimental psychologist whose principal contributions to science lie in the areas of vision and visual perception. Psychophysical and electrophysiological experiments on retinal interaction effects occupied his attention in the 1930's at Clark University. In the 1940's at Brown University he explored animal and human vision by a variety of behavioral techniques and made significant contributions to military problems of visual surveillance and selection of personnel during the Second World War. The remainder of his career, at Columbia University, was devoted mainly to studies of form, depth and motion perception, and the discrimination of color.

Before giving a more detailed account of Graham's life and accomplishments, let me attempt the difficult task of picturing him as an individual. It was in the early days at Clark and at Brown that I knew him best. I can see him now, hands locked behind his head, feet crossed aloft at the right-hand corner of his desk, analyzing the report just handed him by one of his students. "Absurd," he would murmur, but his eyes would be twinkling, and, as likely as not, "poor damned bastard," would be the next remark. Then he would take up a red pencil and cross out large sections of the manuscript, rewriting and re-

rewriting it until it assumed an almost totally new, but immeasurably better-organized form.

With an interest that was wide-ranging and keen, Clarence Graham delighted in observing humanity's foibles, but never without a hint of warm compassion. Each of the men and women, seventy in all, who wrote a doctoral dissertation under his direction can testify to his abhorrence of sloppy thinking and his intolerance of failure to live up to the intellectual capacity one was judged to possess. In Graham's own work, in fact, the standards he held out for himself were so high that he found it difficult to tolerate any error at all. Like all perfectionists, he suffered agonies of remorse over any slip, no matter how trivial, that found its way into his lectures or published articles. Perhaps it was a stern New England upbringing that imposed these strictures upon his behavior, yet allowed him to be among the most generous and considerate of masters in his relationships with a student.

From his birth in 1906 until his doctorate in 1930 Graham remained in Worcester, Massachusetts. His parents had emigrated from County Donegal in Ireland, and his father was a skilled metal worker in a Worcester factory. Clarence was the oldest of four children. He entered public school at the age of five and graduated from high school at seventeen. As a schoolboy he put in long hours, not only in study but also in part-time employment to supplement the family's income and prepare for his own higher education. In an autobiographical sketch he recalled that, during the summer following his graduation from high school, he worked a forty-eight-hour week at a steel wire mill, earning forty cents an hour. Thus was developed the pattern of hard work that lasted him the rest of his life, a pattern that left him no time for idleness and little even for the traditional forms of recreation.

Clark University in Worcester was primarily a graduate school, but in 1923 it accepted Graham as one of a small number of undergraduates to qualify for admission. So strong was

his intellectual curiosity that he started immediately to explore many areas of the humanities and sciences. Finally, after nearly three years of college life, he selected psychology as his major subject. This choice he attributes mainly to the fact that a member of the faculty, John Paul Nafe, took a personal interest in the small band of students who were interested in the laboratory side of psychology at that time. Nafe, whose work was mainly in the cutaneous senses, had what Graham called a magical ability to communicate to others his fascination with the phenomena of perception. This, too, stayed with Graham the rest of his life.

Undergraduate and graduate education overlapped one another at Clark, and the entire faculty of psychology consisted of four men who shared in the teaching at all levels. Graham soon found himself drawn into the graduate program of research, and his formal enrollment in the graduate program followed immediately the attainment of his undergraduate degree. Walter Hunter was the strongest figure of the group, a benevolent dictator who was to be Graham's chief mentor, not only in these years at Clark but also, later on, at Brown. Hunter, at the height of his own research career, early saw in Graham the signs of intellectual talent that would one day take him far beyond the borders of Worcester, Massachusetts.

At the graduate level Graham again explored several possible lines of work before settling down to a final choice. Within the first year experiments on visual perception claimed his main interest and were summarized in his earliest publication (1929). In the subsequent two years of graduate work, Graham became dissatisfied with the subjectivity and essentially qualitative nature of most work in visual perception. In this he was no doubt influenced most strongly by Walter Hunter, who had recently written a paper entitled, "The Subject's Report."

The main thrust of that paper was to reject "introspection" as a method by which a subject analyzes his own sensory processes. Hunter turned the emphasis onto the recording, by the

experimenter, of the language responses of his subject. Graham, indeed, went even further than Hunter in insisting on a behaviorist interpretation of what a subject reports about what he perceives. The whole process is seen as one of setting up the conditions under which the subject is to give a verbal response, preferably a response that is itself restricted to one of a limited number of alternatives. The task of the experimenter is then simply that of taking an objective record of the responses that the subject makes. Thus is the subjectivity of visual perception brought under the objective control of scientific research. This sort of thinking led Graham to use one of the standard psychophysical methods, in which the subject is forced to say "yes" or "no" with respect to his perception of very weak stimuli, in determining binocular summation in the fovea at threshold (1930). Furthermore, the nature of that problem was such that physiological explanations were required. Thus Graham was led to the realization that postdoctoral training in neurophysiology would greatly benefit his career in vision and visual perception.

The year 1930, at the beginning of the period of economic depression, was undoubtedly a most difficult one for finding a postdoctoral research or teaching position, and Graham was fortunate to obtain a one-year appointment in psychology at Temple University in Philadelphia. A five-course teaching load did not discourage him from exploring other opportunities in the Philadelphia area, and soon he made contact with the new laboratory of the Johnson Foundation for Medical Physics. This group, at the University of Pennsylvania, had been established by Detlev Bronk, and two future Nobel laureates were beginning their work there. Ragnar Granit was the one who immediately welcomed Graham as a collaborator in research, and Keffer Hartline later took Graham to Woods Hole for the summer. During that summer, indeed, they accomplished their historic dissection of the optic nerve of *Limulus* in order to

make the earliest records of single-unit activity in the visual system (Hartline and Graham, 1932). Graham won a National Research Council fellowship for the continuation of this work with Hartline in 1931–1932 at the Johnson Foundation. During that year Graham also found time to take a course with Jacobs on the quantitative treatment of experimental data in general physiology. This completed the formal training of Clarence Graham for his lifework of teaching and research in vision, with emphasis on quantification and physiological interpretation of the data.

Three universities were to share in Graham's academic productivity: Clark, 1932–1936; Brown, 1936–1945; and Columbia, 1945–1971. At each in succession he established an experimental facility for vision research, gathered around him a group of graduate and postdoctoral students, and built up the curriculum in the areas of his special competence.

At Clark Graham began a series of psychophysical studies on the spatial interaction that takes place when two or more adjacent areas of the retina are stimulated by light. This program, together with related neurophysiological studies by E. D. Adrian, Granit, and others, he summarized ably in a chapter contributed to the new (1934) *Handbook of General Experimental Psychology,* edited by his colleague, Carl Murchison. Several of his earliest graduate students got their start in research by participating in various parametric experiments that still stand as definitive for human observers under various conditions of light and dark adaptation.

Likewise at Clark, he enlisted my aid in the pursuit of some electrophysiological experiments along the lines of those he had started with Granit and Hartline. An old string galvanometer, borrowed from Hudson Hoagland, was used in early studies of the electroretinogram (ERG) in the rat, pigeon, and frog. For these studies homemade direct-current amplifiers, wick electrodes, animal holders, and shielding equipment were

assembled at minimum cost in a small toolshop used by all the graduate students.

A feature of the ERG experiments on the white rat was to strap the animal to a miniature table and place a cotton wick electrode in contact with the cornea of the eye. Graham was extremely anxious to get ERG records of high quality, and this made it necessary to immobilize the animal by tightening the restraining straps. Graham was caught squarely between his anxiety to get records of high quality and his sympathy for the animal. Throughout the experiment he would repeatedly tighten the straps around the rat's head, meanwhile chanting, "Poor damned animal; poor *damned* animal!"

One more enterprise begun at Clark was Graham's course in the quantitative treatment of experimental data. This seminar gave his graduate students an insight into such mathematical manipulations as numerical transforms, curve fitting, and the testing of hypotheses to account for the results of an experiment. Over the next forty years this kind of course was continued, not only by Graham but by his followers in many other universities. Courses having a similar aim were those of Jacobs in physiology, Daniels in chemistry, and Worthing in physics. But the Graham course for the first time brought experimental psychology into line with other sciences with respect to the processing of data for effective publication in journals and books.

When Hunter was called to the chairmanship at Brown in 1936, he took Graham with him to represent sensory and physiological psychology in a department that had already achieved a considerable status in experimental psychology under the preceding head, Leonard Carmichael. Together with Schlosberg, Hunt, and Kemp they taught large numbers of undergraduates and gradually expanded the graduate program of seminars and research. The old frame dwelling at 89 Waterman Street had to provide offices for all the department, so that the research in

vision had to be conducted in small basement rooms that included a former furnace room and several adjoining coal bins. The judicious use of partitions and hallways made of this basement a suite of cubicles in which both animal and human research in vision could be set up.

The five years at Brown preceding the Second World War Graham has called "some of the happiest of my life." Those joining the staff included Donald Lindsley, Lorrin Riggs, and Carl Pfaffmann. Graduate students brought into the Graham orbit of research included Fred Mote, Robert Gagne, Neil Bartlett, Conrad Mueller, and William Verplanck. Other than teaching, there were few constraints on this group's avid pursuit of experiments. At odd hours, too, classroom space could be used for poker games, ping-pong, and musical outpourings.

World War II brought another phase of Graham's career, that of organizing large teams of research personnel for specific projects related to the war effort. A major portion of this work centered around the visual aspects of gunfire control, especially in the tracking of aircraft targets. Two other team efforts were for the selection of specialized military personnel, and the screening of recruits with problems of emotional instability. The supervision of these projects was at Brown, but they were conducted also at a dozen other locations throughout the country, and about one hundred and fifty persons participated in them. Among those from the Brown psychology group were Bartlett, Berry, Gagne, J. McV. Hunt, Mote, Mueller, Riggs, Solomon, Stellar, and Verplanck. In recognition of his key role in setting up these programs, Graham was awarded the Presidential Certificate of Merit in 1948.

At the conclusion of the war in 1945, Graham was called to his final academic appointment, that of successor to Robert S. Woodworth at Columbia. Thus, at the age of thirty-nine, he ascended to greatly enlarged facilities and opportunities by comparison with those he had left at Clark and then at Brown.

Now he found himself directing as many as eight or ten Ph.D. theses, while at the same time teaching the advanced course for graduate students in experimental psychology and sharing with Selig Hecht a graduate seminar in vision. In 1947 Hecht died, and Graham fell heir to much of his specialized equipment. In addition, Hecht's former collaborator, Yun Hsia, came to work with Graham on problems of color vision. Hsia had been a student in psychology with R. S. Woodworth. Together he and Graham conducted many extensive studies of normal color vision and a number of explorations of color-blind visual functions. Perhaps the most significant of the Graham and Hsia studies was that of a woman with normal color vision in one eye and dichromatic vision in the other. Of particular interest was the fact that this subject saw only two hues in her dichromatic eye; wavelengths shorter than 502 nm were seen as a blue that matched 470 nm as seen by the normal eye, while wavelengths longer than 502 nm were seen as yellow, matching a wavelength of 570 nm as seen by the normal eye. The 502-nm wavelength could therefore be regarded as a neutral point of the spectrum, appearing white to the subject and separating the two basic receptor systems that were present in her dichromatic eye.

A large number of graduate students owe the beginning of their research careers to Graham in his years at Columbia. Among them may be mentioned Munehira Akita, Howard Baker, Shakantala Balaraman, Aleeza Beare, Eda Berger, John L. Brown, John Coulson, Leonard Diamond, John Foley, Barbara Gillam, Elaine Hammer, David Henderson, Robert Herrick, Gerald Howett, Joyce Kerr, Herschel Leibowitz, Alfred Lit, V. V. Lloyd, George Long, Barbara Mates, Leonard Matin, Conrad Mueller, Celeste McCullough, Joel Pokorny, Joan Pollock, Philburn Ratoosh, Vivianne Smith, Harry Sperling, Florence Veniar, Gary Yonemura, and Richard Zegers. Graham's marriage to Dr. Hammer took place in 1949, and she devoted herself to his welfare until his death in 1971.

During the Columbia years Graham edited, and wrote a considerable part of a book, *Vision and Visual Perception* (1965), with co-authors J. L. Brown, N. R. Bartlett, Y. Hsia, C. G. Mueller, and L. A. Riggs. This volume summarized the field in a definitive fashion for students and research workers. Also during these years Graham spent an academic sabbatical leave as scientific liaison officer with the Office of Naval Research in London, 1952–1953. This was an important post in providing contacts between European laboratories and those of the United States in experimental psychology. During a visit to Japan in August and September of 1952, he conducted an intensive seminar for faculty members from several of the leading Japanese universities, to acquaint them with research going on in the United States in vision and visual perception. A direct result of this enterprise was the visits to the United States of a number of the participants and their students, some of whom completed their graduate or postdoctoral education in this country. Indeed, it is true that Graham introduced such topics as visual contrast and figural aftereffects into Japanese experimental psychology.

During the last four years of his life, Graham suffered several physical setbacks, including a heart attack, pneumonia, and a broken hip. With care and encouragement from his wife, he kept up his writing and maintained contact with his laboratory. Even under these trying conditions he continued to be generous of his time and interest in his graduate students. But the uphill fight was lost in the summer of 1971, and he died on July 25. A memorial service was held on August 6 at which many of his former students, friends, and associates paid tribute to his memory.

Among the honors accorded him during his lifetime are the following: Howard Crosby Warren Medal, Society of Experimental Psychologists, 1941; election to the National Academy of Sciences, 1946; Presidential Certificate of Merit, 1948; Honorary Sc.D. Degree from Brown University, 1958; Certificate of

Appreciation, Office of Naval Research, 1961; Tillyer Medal, Optical Society of America, 1963; Distinguished Scientific Contribution Award, American Psychological Association, 1966.

The book *Vision and Visual Perception* will unquestionably stand for a long time to come as a monument to its editor and principal author, Clarence Graham. Aside from its factual material, uniquely present in this one volume at the time of its publication, in 1965, the book exemplifies three of the main themes of Graham's own life.

First, and most important, is the theme of objectivity. Undoubtedly, the objective orientation of the book owes itself to the behaviorist tradition in American psychology, a tradition with which Graham was closely identified through his early association with Walter Hunter and his later contacts with B. F. Skinner. His introductory chapter, "Some Basic Terms and Methods," goes to great lengths (some would say too great lengths) in expounding the behaviorist views on such visual sensations as hue, brightness, and saturation. Of hue, for example, Graham says, "The term is to be understood as either a label for or as an inferred effect . . . in the following stimulus–response sequence: (a) instructions to a subject who has had a past history with the vocabulary represented in the instructions, (b) the presentation of radiant energy to the subject, and (c) the subject's responses." In a later chapter, Graham quotes Skinner, with respect to the names that are attached to hues, as follows: "If the person says 'green' to light of wavelength 530 mμ, such a response obtains social approval; it is the 'correct response.' " The point of all this is to approach the entire subject of color vision with the aim of avoiding the ambiguities that might creep in if anything so personal and subjective as color naming were to be used as a major source of information. Instead, Graham emphasized that truly scientific studies of color vision must fulfill the criteria of objectivity. That is, the stimulus situation must be carefully specified and controlled, and the responses of the subject must be carefully tabulated by the

experimenter. Among the stimulus conditions are not only the primary ones, such as the wavelength, luminance, and other dimensions of the light, but also the instructions to the subject and the various environmental and physical conditions under which the experiment is carried out. The instructions should typically limit the subject to two possible responses, such as "match" or "mismatch" in the case of color judgments and "seen" or "not seen" in determining a threshold. Standard psychophysical procedures may then be used to estimate the critical value of the stimulus at which the judgment shifts from one category to the other; this value yields a quantitative definition of the subject's sensory discrimination. Certainly, it is true that objectivity was an important consideration in the selection of material to be included or excluded in the coverage of the Graham book, particularly with respect to certain fields of visual perception.

A second point of major emphasis in Graham's thinking was the physiological basis for vision and visual perception. In this regard he differed strongly with Skinner and other psychologists of behaviorist backgrounds. Perhaps it was his lifelong association with neurophysiologists, beginning with Granit and Hartline, that led him to the conviction that hypotheses about vision should be mainly physiological. In any event, he included in the coverage of the 1965 book specific chapters on the structure, electrophysiology, and photochemistry of vision. Furthermore, a majority of the specific topics in vision and visual perception are handled in such a way as to emphasize the probable physiological bases for the findings.

The third characteristic of Graham's approach to vision, also clearly exemplified in the book, is his attention to the quantitative analysis of data. There are many instances of his care in fitting curves to data, testing theoretical models against experimental results, and illustrating by graphical displays the essential features of research information.

Those of us who were privileged to write doctoral disserta-

tions under Graham's direction remember his meticulous editing of manuscript, checking and rechecking of data, and laborious reworking of tables and graphs to maximize useful information from our experimental findings. From their exposure to this kind of scientific experience, the more than seventy graduate students—at Clark, at Brown, and at Columbia—who completed their work for the Ph.D. degree under his direction learned that hard work and generosity were part of the game, but compromise, never. By the wider community of scholars Graham will be remembered for his high scientific standards and for his dedication to the fields of vision and visual perception.

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KEY TO ABBREVIATIONS

Am. J. Physiol. = American Journal of Physiology
Am. J. Psychol. = American Journal of Psychology
J. Cell Comp. Physiol. = Journal of Cellular and Comparative Physiology
J. Exp. Psychol. = Journal of Experimental Psychology
J. Gen. Physiol. = Journal of General Physiology
J. Gen. Psychol. = Journal of General Psychology
J. Opt. Soc. Am. = Journal of the Optical Society of America
J. Psychol. = Journal of Psychology
Proc. Natl. Acad. Sci. = Proceedings of the National Academy of Sciences
Psychol. Rev. = Psychological Review
Vision Res. = Vision Research

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