CLINICAL AND EXPERIMENTAL
OPTOMETRY

PROFILE

Professor Gerald Westheimer FRS Australian optometry's pre-eminent vision scientist

A hypothetical poll of the international community of vision scientists for the names of optometrists who have made significant and fundamental contributions to basic research in vision would undoubtedly and by a wide margin place Gerald Westheimer at the top of the list. This is a prediction that can be made confidently on the basis of the number and stature of the awards and accolades that he has received, the impact of his more than 200 scientific papers and the importance of the committees on which he has served.

Of equal importance to this hypothetical exercise is the widespread recognition of his optometric background. Throughout his career and his long affiliation of more than 30 years with the Department of Physiology–Anatomy (lately renamed the Department of Molecular and Cell Biology) at the University of California at Berkeley, he continued to define himself as an optometrist and openly acknowledged the value to his scientific career of the rigour of his training in optometry at the Sydney Technical College, followed by his studies in physiology and mathematics at the University of Sydney, where he completed a BSc in 1948.

Gerald Westheimer (centre) at the Festschrift held in his honour at the University of California Berkeley in August 1989. On his left is the late Dr Glenn Fry who was Gerald Westheimer's PhD supervisor in 1951 to 1952 in the College of Optometry at Ohio State University. Dr Fry was the Director of the College and a remarkable vision scientist who, among other things, gave us the concept of the AC/A ratio. On his right is Donald Mitchell, the author of this profile, who did his PhD under the supervision of Dr Westheimer 16 years later. Dr Mitchell is a graduate in optometry at The University of Melbourne and is now a Professor of Psychology at Dalhousie University, Canada.

Because he is an Australian and an optometrist, most readers of this journal would be aware of the major awards that Gerald has received and know the key steps in his career. For this reason and because three excellent published biographies of Gerald's scientific career by Wright,[1] Alpern[2] and McKee[3] have already been published and can be consulted for missing details, I will summarise only briefly the highlights of his academic career. Thus, I can say something about what I learned of Gerald Westheimer as a vision scientist and mentor during the three years from September 1965 to October 1968 that I spent as his graduate student at Berkeley, California. In so doing, I hope that this glimpse into life in the Westheimer laboratory may provide insights into how he rose to such international scientific prominence from what many might consider humble academic origins.

Gerald was born on 13 May 1924 in Berlin in Germany and for a short time lived essentially a normal life, albeit one that

showed extraordinary academic and musical promise. The rapid escalation of state-sanctioned attacks against Jews in Nazi Germany in the 1930s that culminated in physically violent activities propelled the Westheimer family to seek refuge abroad.

They applied for immigration permits to Australia, which, thankfully, were granted, allowing the family to settle virtually penniless in Sydney in 1938. The pecuniary circumstances in which the family found themselves meant that Gerald had to work, first as an office boy in a department store and then in the optometric practice of Mr EJ Jackson, where he was apprenticed while concurrently studying optometry at night at the Sydney Technical College. He qualified in optometry in 1943 at the age of 19, which allowed him to proclaim to his friends in later life that: 'I was a teenage optometrist'. He became an Australian citizen in 1944 and is proud to retain citizenship despite having lived in the USA for 50 years. On qualification, he was made a partner in Mr Jackson's practice but was not formally registered as an optometrist until 1945, on reaching 21 years of age.

After obtaining his optometric qualification and while practising the profession during the day, he continued his studies at night at the University of Sydney. Gerald worked full time as an optometrist with Mr Jackson until 1951, when he left for the USA to further his education. During the six years he spent in Australia as a registered optometrist, he made a strong impact on his contemporaries, particularly Don Schultz. I now realise that certain of the habits and opinions Gerald learned then remain with him to this day.

One example comes from when we were both invited as guest speakers at the Australian Optometrical Association Bicentennial Congress in Manly in 1988. We had both decided not to attend a lecture on a clinical topic and he remarked that he felt a twinge of guilt for not attending, as he would never have missed such lectures when he lived and worked in Sydney. In addition, he formed a strong opinion of the common sense of Australians and is full of praise for the solid education he received. The latter notwithstanding, the restricted ability to conduct research and to pursue higher degrees in Australia in the years prior to the mid-1950s led to a number of now-prominent scientists, Gerald included, travelling overseas to further their education. It is instructive to read biographies of some of these individuals, such as Bernard Katz[4] and Stephen Kuffler,[5] to gain an appreciation of the limited opportunities for academic advancement—as well as the interesting criteria used in hiring—in Australia in the immediate post-war years compared to those that exist today.

Alpern's[2] biography provides details on correspondence that resulted in Gerald being admitted to Ohio State University, where he completed a PhD in physics in only two years, supervised by Dr Glenn A Fry in the School of Optometry. The research for his dissertation on saccadic and pursuit eye movements resulted in two published papers[6,7] that are regarded as seminal papers in the field, as they introduced linear control theory to the study of oculomotor control. The continued impact of these two papers is demonstrated by citation statistics (Science Citation Index) that reveal, for example, that since 1989 they have received more citations than all but two of his other papers.

In recent correspondence with me, he admitted to still being puzzled about what it was about his dissertation that 'hit the right reverberation point in science' as the ideas did not come from Glenn Fry and the work was completed long before he had met the Cambridge people 'or any other important American scientists except Paul Fitts'. He mentioned that the concepts were established within about a year of arriving from Australia and postulates that 'something about the then Australian undergraduate education helped foster it'.

After completing his PhD, Gerald spent a year in 1953–1954 at the University of Houston, followed by six years at Ohio State University—in the School of Optometry in both institutions. During the last few years at the latter institution, he spent a year on leave at Cambridge University, where he worked with Fergus Campbell and John Robson on accommodation. While in England, he met the other members of the Cambridge group of visual physiologists, notably Horace Barlow, Giles Brindley and William Rushton, all of whom had an important impact on Gerald's research for the next decade in terms of the issues that he addressed and the manner in which he conducted experiments. He initiated collaborative experiments with many of them and began a fruitful collaboration with Cyril Rashbass in London on vergence eye movements.

In 1960, Gerald moved to become Associate Professor at the School of Optometry at the University of California at Berkeley, where he was later joined by Horace Barlow. He achieved the rank of professor in 1963 and in the same year, became Chairman of the Graduate Group in Physiological Optics, the co-operative group of departments (Medical Physics, Psychology and Optometry) that awarded the PhD degree in physiological optics at Berkeley. In 1967, he and Horace Barlow moved across campus to the Department of Physiology-Anatomy that later was expanded and renamed the Department of Molecular and Cell Biology. Although Horace Barlow returned to Cambridge shortly thereafter, Gerald has remained in the department to this day.

Gerald's attitudes towards science and his concerns for humanitarian issues were made evident on the very day of my arrival at Berkeley as an extremely naive graduate student in September 1965. As apparent from the brief sketch of Gerald's academic history, I arrived several years after he had moved to Berkeley but at a time when the influence of his Cambridge colleagues was still very strong. September 1965 was also an interesting time from another perspective, as it coincided with the beginning of the academic year following the turbulent events surrounding the Free Speech Movement that included the student occupation of Sproul Hall.

With the rapid growth of telecommunications in all its guises from television to the internet and international travel now commonplace, it may be hard for younger readers to imagine the true feeling of culture shock that I experienced for the first few weeks after my arrival.

Gerald was kind enough to meet me at the San Francisco airport, which was fortunate as he saved me from walking into the path of a car as soon as I walked out of the front door of the terminal. The conversation we had during the hour-long drive from the airport to Berkeley is still vivid in my memory. After a discussion of the research that I had done for my master's thesis in Melbourne, in which he revealed his exhaustive knowledge of the literature on binocular vision, he described graduate education at Berkeley. Following this, he began a long monologue on the events of the previous academic year, including his thoughts on the issues that had motivated the actions of the student protestors.

Beyond the issue of freedom of expression on campus that was the immediate reason for the occupation of Sproul Hall, Gerald believed that students were expressing their underlying rejection of the materialistic nature of US society as well as protesting about other social ills such as racial and economic imbalances.

As an aside, I should mention that while Gerald ticked off a number of excesses of US society, I was receiving my first exposure to many of the material aspects of this society for the very first time. I had never seen a freeway and the cars appeared to be models that were 10 years advanced from those I had seen in Melbourne. He mentioned that many households had multi-coloured television sets at a time when I had never seen colour television. In Melbourne, I had access only to an old black and white television set that could at best be described as an abstractly illustrated radio.

What really impressed me was his deep concern for the students and his appreciation of the potential and, as it turned out, very real consequences for them of their actions. The sit-in of Sproul Hall ended with the arrest and detention of more than 1,000 students and the eventual conviction of many of them. The latter students, because of their criminal conviction, were forever unable to obtain the security clearance necessary for employment in the aerospace and electronic industries that were the largest employers of graduates in science and engineering in California at the time. Gerald personally provided bail for a number of these students and hired at least one, Lee Felsenstein, for an extended period during my stay in Berkeley to help develop an electronic keratometer.[8] Incidentally, Lee later became the moderator of meetings of the Home Brew Computer Club, a group of computer and programming enthusiasts that met in Palo Alto on a regular basis to discuss issues relating to computing. Lee went on to help design the Osborne portable computer and other members of this group founded 23 IT companies including Apple computer.

On arrival at his house, where Gerald kindly hosted me for two or three nights before I found permanent accommodation, he handed me a reprint of Hubel and Wiesel's latest paper on the responses of cells in area 19,[9] which had only just been published but had not yet arrived in Australia. Although he did not explicitly request that I read the article immediately, I went to bed assuming that this was expected and that I would be quizzed on its contents in the morning. Due to tiredness from the long trip and the concentration required to absorb all that I had just been told, I fell immediately into a deep sleep without more than glancing at the paper. Fortunately, he did not refer to the paper the next morning, so I was able to read it later that day.

Within a few hours of my arrival, I had learned of most of Gerald's unique qualities, including many of those that contributed to his success as a scientist. The events of the first day had informed me of his amazing analytical skills, his extremely high intellect and his knowledge of the literature. In retrospect, I realise that his enthusiasm for the paper of Hubel and Wiesel revealed his ability to look beyond his immediate research pre-occupation to results and concepts that would shape the issues that he would address in his future research program.

In the next few days, I was to learn of two more of Gerald's attributes, namely his encyclopaedic memory for facts—many useless as he was fond of saying—and his fascination with optical and electronic equipment and devices. On arrival at a new place or at a new place of employment, it is necessary to fill out many forms that list one's personal details and a complete history of one's education. After one reading, Gerald would remember without error all of these details and on occasions, when handed a blank or partially completed form for his signature, he would enter all the remaining required bits of information, having memorised without conscious intention or effort, the birth dates, social insurance numbers, car registration numbers and educational history of many people.

On being shown his laboratory for the first time, I was amazed at the number and variety of optical and electronic components that he possessed. He knew where they were all carefully stored and as he held each one would announce the experiment and resulting publication for which that particular item had been used with the words: 'This lens (device) was published in *Journal of Physiology*, Volume X, page Y, 19ZZ'.

In a serious vein, Gerald's ingenious adaptation of new devices enabled him to automate the running of experiments at a time long before minicomputers made it commonplace. On any Saturday morning, on walking by the closed door of his laboratory, one could hear the noise of a printer writing the output of a potentiometer that read the position of an optical wedge as Gerald, serving as his own subject, set a visual threshold. More important than allowing automation of his experiments, his knowledge of optics and of electronics provided him with the ability to find ways to make new measurements such as the contrast sensitivity for sinusoidal interference fringes formed directly on the retina,[10] measurements of line spread functions in living eyes[11,12] and spatial interactions in scotopic and photopic vision.[13,14] In the 1970s, he embraced computers with a vengeance and used them to replace conventional optical systems to display visual stimuli, particularly those employed for his many landmark studies of the visual hyperacuities.

The years immediately prior to my arrival at Berkeley marked a transition of

sorts in the nature of Gerald's scientific interests. Whereas his earlier work could be characterised as having been primarily centred on studies of eye movement control and of the image quality of the eye (through study of its various optical components and measurements of line spread functions), his new work employed psychophysical methods to explore stimulus factors that affect human visual performance from simple detection thresholds for light to spatio-temporal vision in all its various aspects from the various spatial acuities to stereoscopic vision.

In the year of my arrival, he published his study of spatial interactions in scotopic vision[13] that provided information on the dimensions and organisation of concentrically organised receptive fields in the human retina. He told me that this work had begun with unsuccessful earlier attempts in collaboration with William Rushton in Cambridge but after he had returned, he had thought of a new approach that ultimately proved successful.

On my arrival, I assisted on the last minor part of this research[14] on spatial interaction in photopic vision. These papers could be considered as the first tangible evidence of the change in the nature of his research direction due to the influence of the Cambridge group, an influence that arguably continues to this day. These papers and the majority of others that followed were informed by contemporary understanding of the organisation and receptive field characteristics of neurones at various levels of the visual pathways from the retina to the striate cortex and beyond.

Underlying the majority of these studies has been a desire to derive an understanding of the neural basis for perceptual performance through documentation of the important parameters that influence perceptual performance that, in turn, help refine predictions based on electophysiological investigations on animals. The study I conducted under his direction for my PhD dissertation on the sensory stimulus for disjunctive eye movements represented one of the first investigations from his laboratory that was influenced heavily by contemporary understanding of the characteristics of receptive fields of neurones beyond the retina, in this case those of binocular neurones in cat striate cortex.

This overview of Gerald's research from the early 1960s serves as background to the influence of certain colleagues at Cambridge and others on his research. By the time I had arrived, he had observed the best vision researchers in the world at close quarters and had formed a set of opinions of the value of certain approaches to science and how research should be conducted. Moreover, the influence of these colleagues was made evident to me shortly after my arrival by the frequent number of visitors to his laboratory. In the first six months, he received visits from Giles Brindley, Fergus Campbell, John Robson and John Dowling, to name just a few. On many a day, Gerald would walk into the laboratory and chat for hours on science in general, during which, I now recognise, he defined a set of values and provided me and my fellow graduate students with a number of important principles and guidelines, by which he hoped we might operate.

In terms of his set of values, it was apparent that he admired single-minded solid experimental attacks on a problem rather than flashy single experiments, following which the investigator turned to a completely different issue. For example, he admired the work of groups like those of Hubel and Wiesel and the group in Canberra headed by Peter Bishop.

Another of his values that remains vivid in my memory was his opinion of the greater eventual value of research conducted in a spirit of co-operation, as opposed to research conducted in a highly competitive and sometimes combative fashion, where a pecking order is well-defined with an acknowledged leader.

As an analogy, he used different methods for hitching dogs to a sled. The analogy for the first approach is the fan hitch, used by the Inuit in Canada and Greenland, where each dog is tethered by its own rope of equal length attached to one loop in front of the sled (qamutiq). The analogy for the second approach is an arrangement used by early trappers and voyagers of a single line of five dogs (or the modification introduced by European explorers in Arctic regions of five sets of paired dogs) with only the lead dog at the front having a good view of the way ahead. Another piece of advice we received as graduate students (that was not easy to reconcile with other advice) was to make radical switches in the course of one's career to attack different research issues.

In no particular order, the other lessons I learned from Gerald concerning the manner in which research should be conducted and papers written were as follows. First, a paper should make only a single point. Second, it should be possible to comprehend the important message of a paper by reading the title, the abstract and the figure legends. Finally, in a less serious vein, he was sometimes heard to say that there were only two important papers in a field, the first and the last. Since then, I have learned of one other tongue-in-cheek piece of advice that has been attributed to the late Donald Hebb, the distinguished Canadian psychologist, namely, that if an experiment is not worth doing, it is not worth doing well.

As summarised in previous biographies, Gerald has received many honours, most notably interdisciplinary awards such as the Tillyer Medal (Optical Society of America) in 1978, the Proctor Medal (Association for Research in Vision and Ophthalmology) in 1979, the CF Prentice Medal (American Academy of Optometry) in 1986 and the von Sallman International Prize in Vision and Ophthalmology in the same year. In addition, in 1985 he was elected as a Fellow of the Royal Society of London, the first optometrist to be so recognised. Of course, he has also received many optometric awards including honorary doctorates from the State University of New York and his alma mater, The University of New South Wales.

With such wide acknowledgment of the value of his many contributions to vision science, readers may find it interesting to learn that in the late 1960s he confided that despite much wider recognition of his other papers, one highly mathematical paper[15] on the kinematics of the eye of which he was very proud received only two reprint requests and very little acknowledgment. At the time, he was also very proud of another paper[16] on the Maxwellian view

because of its unusual lack of references. In recent correspondence, Gerald mentions that one of the two reprint requests for the kinematics paper came from Aaron Klug, later Sir Aaron Klug OM, winner of a Nobel Prize and President of the Royal Society. When Gerald met him on the occasion of his Ferrier lecture to the Royal Society in 1992, he remembered having requested the reprint.

Along with the important insights that Gerald's papers provide on various issues, his papers stand as shining examples of clear exposition, an enviable quality that is all the more remarkable in view of the fact that English is his second language. Over the years, Gerald's work has continued to evolve to address higher levels of perception such as illusions, illusory contours and perceptual learning, as well as collaborative work with Charles Gilbert[17] that addresses the influence of attention, context and learning in the striate cortex.

Although Gerald has officially retired, he retains an emeritus position at Berkeley and continues to publish on a regular basis. Moreover, his collaboration with Gilbert and Wiesel continues in his retirement, so that we can look forward to many more challenging papers from Gerald in the future. He mentions that for him events have come full circle in 50 years; then as now he has only a single dark room as a laboratory in which he performs everything himself from programming to serving as a subject, to drawing figures and preparation of the final manuscript.

Vision research in general and optometry in particular owe a great debt of gratitude to Gerald Westheimer for the extremely valuable body of work that he has provided and which continues to grow in his retirement. Although it may be easy to attribute his success to his obviously high intellect, I think he would be the first to admit that many of his valuable insights were gained from the unique perspectives gained from his position between the borders of the academic disciplines in which he received his early training—optometry and physics—and between his dual linguistic and cultural backgrounds.

Finally, on a personal note, I would like to take this opportunity to thank Gerald for the inspiration and advice that he provided during my time as his graduate student and in the years that followed.

REFERENCES

1. Wright CW. History of Australian Optometry. Carlton, VIC: Australian Optometrical Association, 1988: 206-208.
2. Alpern M. On presentation of the Proctor Medal of the Association for Research in Vision and Ophthalmology to Gerald Westheimer. *Invest Ophthalmol Vis Sci* 1979; 18: 883-892.
3. McKee SP. Optics, physiology and vision. Introduction. *Vision Res* 1990; 30: 1529-1530.
4. Katz B. Bayliss-Starling Memorial Lecture (1985) reminiscences of a physiologist, 50 years after. *J Physiol* 1986; 370: 1-12.
5. McMahan UJ. Steve. Remembrances of Stephen W Kuffler. Sunderland, Massachusetts: Sinauer Associates, 1990.
6. Westheimer G. Mechanism of saccadic eye movements. *Arch Ophthalmol* 1954; 52: 710-724.
7. Westheimer G. Eye movement responses to a horizontally moving stimulus. *Arch Ophthalmol* 1954; 52: 932-941.
8. Westheimer G, Felsenstein L. Automatic photoelectric keratometer. *J Opt Soc Am* 1966; 56: 807-810.
9. Hubel DH, Wiesel TN. Receptive fields and functional architecture in two nonstriate visual areas (18 and 19) of the cat. *J Neurophysiol* 1965; 28: 229-289.
10. Westheimer G. Modulation thresholds for sinusoidal light distribution on the retina. *J Physiol* 1960; 152: 67-74.
11. Westheimer G, Campbell FW. Light distribution in the image formed by the living human eye. *J Opt Soc Am* 1962; 52: 1040-1045.
12. Rushton WAH, Westheimer G. The effect upon the rod threshold of bleaching neighbouring rods. *J Physiol* 1962; 164: 318-329.
13. Westheimer G. Spatial interaction in the human retina during scotopic vision. *J Physiol* 1965; 181: 881-894.
14. Westheimer G. Spatial interaction in human cone vision. *J Physiol* 1967; 190: 139-154.
15. Westheimer G. Kinematics of the eye. *J Opt Soc Am* 1957; 47: 967-974.
16. Westheimer G. The Maxwellian view. *Vision Res* 1966; 6: 669-682.
17. Gilbert C, Ito M, Kapadia M, Westheimer G. Interactions between attention, context and learning in primary visual cortex. *Vision Res* 2000; 40: 1217-1226.

Author's address:
Donald E Mitchell
Psychology Department
Dalhousie University
Halifax NS B3H 4J1
CANADA