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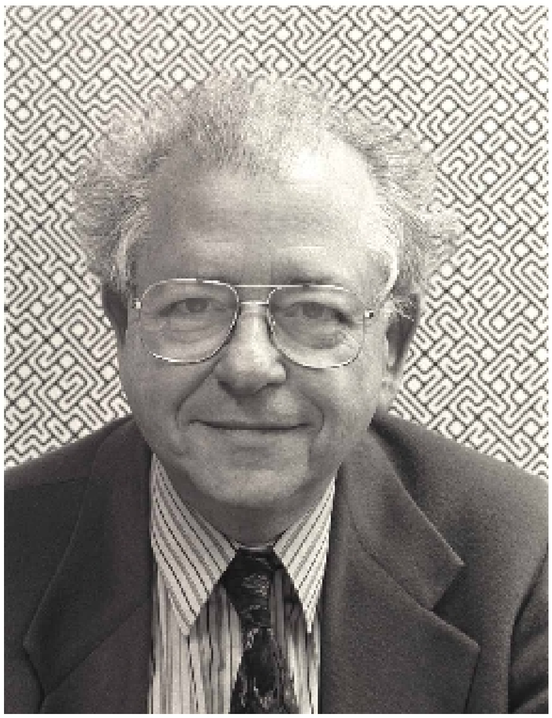
Bela Julesz 1928 ^ 2003: A personal tribute



Bela Julesz was one of the outstanding vision scientists of his generation. He was the leader in introducing a new empirical paradigm to visual psychophysicsöexploiting complex computer-generated stimuli with precisely controlled characteristics. He used a wide and imaginative range of these stimuli to explore many facets of vision. His basic demonstrations using random-dot stereograms (RDSs) have stunned and stimulated many generations of students as they have become essential core material in the psy- chology of visual perception. RDSs have also had important practical applications, for example in testing for stereopsis. Many members of the general public will have shared the surprise and delight in fusing RDSs as they have been widely published and also shown on television. These sorts of stimuli also decorate many a wall. He stimulated many others to work with similar sorts of stimuli, leading to rapid and widespread advances.

Julesz's achievements received due recognition with a number of distinguished awards (these are listed on the Rutgers University website at http://zeus.rutgers.edu/julesz.html and at http://ur.rutgers.edu/medrel/viewArticle.html?ArticleID=3697). I mention just two here. First, he received in 1985 the Dr H. P. Heineken Prize from the Royal Netherlands Academy of Arts and Sciences, jointly with Dr Werner E. Reichardt. He noted that his work and that of Reichardt shared a common theme: the realisation of the importance to vision of cross-correlation. Second, he gave the Perception Lecture in 1988 to the 11th ECVP. This was the first of the invited lectures at ECVP to be sponsored by Perception. It must surely have the longest title of that lecture series: ``In the last minutes of the evolution of life, stereoscopic depth perception captured the input layer to the visual cortex to break camouflage''.

I have warm memories of Julesz. I first met him in 1971 as a postdoc funded by the MRC to work with him at Bell Labs New Jersey. I had just got a lectureship and I had put in my first grant application for a psychophysical project studying orientationally tuned binocular disparity mechanisms using random line stereograms. This project was stimulated in large part by Julesz's work. Lacking his computer facilities, I had been using stereograms comprising photographs of bits of chopped-up chicken fence wire stuck into a cardboard mount. MRC wisely judged that, rather than have me proceed in this quaint fashion, I should be sent off to learn my trade properly with Julesz. They funded a postdoc position for 3 months, for which I remain eternally grateful. Colin Blakemore had a hand in this decision as he also had worked with Julesz at Bell Labs (Blakemore and Julesz 1971) and so he knew from first hand the benefits that could flow from a short-term visit there. I thus became one of a number of young collaborators to whom Julesz was extremely kind and accommodating throughout his career.

I well remember desperately trying to absorb Julesz's magnum opus, Foundations of Cyclopean Perception (Julesz 1971), which had just come out, in a hotel while I waited over a weekend for Monday to come around and for me to present myself humbly to what I feared would be the unapproachable Great Man in the Citadel of High Tech Studies of Vision. When I did get to see him and his facilities, the contrast between the technical sophistication and opulence of Bell Labs and my little bits of chicken wire was indeed massively daunting. But Julesz's friendliness soon settled me down and I embarked on a monkish postdoc routine of delightful 10+ hour days in his lab luxuriating in his fantastic facilities, without a student to teach or a committee to attend. Wonderful days! He invited me to his home where I met his charming wife Margit and his two hyperactive dogs. I recollect him joking that the personalities of dogs and people were similar in all important respects; they just differed in their input requirements for blissöbones vs Mozart.

This demonstrates a particularly engaging aspect of Juleszöhis enormous fund of jokes and stories. He made a point of telling them only if they were a propos the ongoing discussion. He regarded it as very bad taste for jokes to be told just for the sake of telling them. In writing this tribute, I have tried to find a joke that he might have liked to be included here, as a fitting comment on his life and work. Sadly, I have failed to find one. One of his jokes that I find remarkably often apposite is: Count your chickens before they are hatched, because they are so rarely worth counting afterwards.

The help Julesz gave to young academics trying to get established was a consequence both of his generous nature and his own bitter experiences trying to make his way as a young scientist. He had fled the Russian invasion of Hungary in 1956 by immigrating to the United States. His background was in electronic engineering. His PhD was awarded by the Hungarian Academy of Science in 1955 and was entitled: Analysis of TV Signals by Correlation Methods. His first work at Bell Labs produced a paper entitled ``Method of coding television signals based on edge detection''. These two titles help explain why he was so well placed to exploit engineering ideas in the study of perception, the field that was to become his life's work. He saw much of his thinking as the fruit of ``a clash between two cultures, an association between two foreign languages (that of the psychologist and the engineer) in the head of a bilingual'' (Julesz 1986).

When Julesz became interested in perception and he began reading the psychological literature on stereoscopic perception he reports: ``I was startled to learn that according to the prevalent notions of psychologists at the time, stereopsis was an enigmatic problem, based on monocular form-recognition, shrouded in the mystery of semantics, and complicated by the many familiarity cues that are needed to recognize, say, a face _.

As a former radar engineer, I knew that this view of psychologists could not be valid. After all, in order to break camouflage in aerial reconnaissance, one could view aerial images (taken from two somewhat different positions) through a stereoscope and the camouflaged target would jump out in vivid depth'' (Julesz 1986). From this sprang the idea of using one of the first big computers, an IBM704 that had just arrived at Bell Labs, to create artificially camouflaged objects. Thus dawned the era of complex computer-generated stimuli in vision research.

Julesz had great difficulty getting his initial work on RDSs into journals, being blocked by Kenneth Ogle who apparently never properly understood the way RDSs were created. Ogle reckoned that RDSs contained monocular cues to the disparate zones due to imperfect placement of the texture elements in each stereo half-image. Julesz argued, without success as far as Ogle was concerned, that computer-controlled element placements in integer steps (pixels) ensured such cues were absent. This initial difficulty in publication led him to resolve, he told me, that he would never himself create similar problems for young scientists. However, it is interesting to note that he says this episode made him ``convinced that it is more important for a young, unknown scientist, to have a famous scientific rival than a powerful patron (of course, the young man has to be right!) _ the scientific controversy between Ogle and me drew attention to my findings perhaps sooner than would otherwise have been the case, and hastened their acceptance by the scientific community.'' (Julesz 1986). Perhaps this is an instance of the blessings of hindsight in diminishing painful memories.

The quotation above on stereopsis reveals that Julesz was very well aware of precursors to his computer-generated RDSs. Indeed, I recollect him telling me that he saw RDS as essentially trivial, a mere technique, and he retained that opinion where he says: ``Let me note that I never regarded my role of introducing random-dot stereograms into psychology as a great intellectual achievement _.'' (Julesz 1986) But his precursors who had utilised non-computer generated stimuli similar to RDSs had neglected to see their enormous potential. Or, if they had seen it, they did not have the computer facilities to exploit it. The precursors to RDSs do not detract in any important way from Julesz's achievements. The Foundations of Cyclopean Perception is a remarkable testament to the empirical and theoretical ramifications that Julesz drew from RDSs, random-dot cinematograms, etc. And this work was completed in a remarkably short timeöthis book came out only about a decade after his first RDSs paper in the Bell System Technical Journal (Julesz 1960). That book also describes the work of many others who were stimulated by Julesz to use his sorts of stimuli in those heady days when the increasing availability of powerful computers made so many new experiments possible.

What were the achievements that flowed from his introduction of RDSs to the study of perception? His own list (Julesz 1986) would form a good starting point for any biographer and/or historian of research in visual perception. He says: they were ``one of the earliest non-trivial applications in psychology, creating stimuli with exactly controlled stochastic and geometric properties''; they unequivocally demonstrated that binocular depth perception does not depend on high-level monocular form recognition, and he believed this contributed to the shift of neurophysiological research from higher- level problems to the search for binocular disparity-tuned neurons in the early stages of the visual pathway; they suggested that the correspondence problem in stereopsis could be a rewarding system to model as it was challenging but tractable, and this led to much work on computational models of stereo; they provided a robust test technique for screening for stereopsis, including evoked potential testing on human infants using RDSs; they could be used to portray and elicit most of the known perceptual aftereffects and optical illusions, thereby providing insights into their locus in the visual processing hierarchy, in a research programme that Julesz dubbed `psychoanatomy'.

That is an impressive list by any standards and yet Julesz he did not regard his work on stereopsis as his major concern, at any rate in the early 1970s when I worked with him. He told me that he saw RDSs as a bit of a sideshow from his main preoccupation, which was monocular figure ^ ground perception. He regarded his work on texture perception as potentially of far more fundamental significance. I do not know whether he held to that view later in his career. Time may well prove him right, as an informal citation check suggests that his most cited papers (discounting the very early ones that described his initial findings using RDSs) were on texture. In these, he and his collaborators reported a great deal of evidence, using textures created with sophisti- cated mathematical controls, that the preattentive human visual system cannot use global (statistical) texture parameters but instead uses local conspicuous features. He coined the term texton for these stimulus elements. Textons are elongated blobs of specific colours, orientations, widths, lengths (and also of binocular disparity, velocity, and flicker rateöJulesz 1987). He concluded that preattentive parallel vision can detect only texton gradients where adjacent texture elements differ in their texton number or density. It cannot recognise the positional relationships between textonsöthat requires focal attention. It is my impression that the term texton has not really caught on as part of the frequently used terminology of the field. I have searched the indices of various standard texts on vision and not all of them include it. Time will tell whether this apparent neglect, if such it is, is vindicated.

In considering Julesz's achievements I am reminded that he once told me that he regarded his own talents in exploiting RDSs as completely dwarfed by the brilliance of the computer engineers and programmers who had made RDSs possible. Also, he always acknowledged fully the great help he had from mathematicians and programmers at Bell Labs. One of his programmers who greatly helped me during my stay was Joan Miller, who published with Julesz an important and highly cited paper in Perception on spatial-frequency-tuned channels for stereopsis (Julesz and Miller 1975). I remember while at Bell Labs serving as a subject in an experiment she was running for Julesz. Although Bell Labs gave Julesz a pretty free hand to do much as he liked, he was nevertheless encouraged to find useful applications of his research. Hence he was explor- ing the potential of a bandwidth-reduction technique for video phones. The idea was to measure where a user was looking and display high-resolution imagery only in a small area centred on the patch of the image projected on to the fovea at any given moment. I do not know whether anything came of this, but I do know that the experiment gave me a pair of very sore red eyes caused by the infra-red eye-movement-detecting kit they were using. This was of course a small price to pay for all the fun I had there.

Julesz's modesty could be set aside on occasion by what some regarded as a streak of the Prima Donna. He told me that he was shocked when, in a preface to a book, I placed David Marr at the head of my list of those whose work had most influenced me. ``What had Marr achieved?'' he complained, implying that his own achievements far outstripped those of Marr. Julesz was clearly irked by being relegated even in my inconsequential preface to a less influential place. It is evident that Julesz's empirical achievements do indeed far outstrip those of Marr, and indeed of most vision scientists of the last 50 years in my opinion. On the other hand, it is arguable whether his theoretical contributions have anything like the same status. His parallel-dipole model of stereopsis (see Julesz and Chang 1976) is not often used nowadays. Its metaphor of magnets and springs, as a way of using the disorder/order transitions in magnetic materials to model certain phenomena in binocular vision, clearly reflects Julesz's engineering background. It served a purpose at the time, but nowadays perhaps that clothing obscures rather than reveals the deep structure of the model. At any rate, the current Zeitgeist favours computational models of stereopsis that utilise neural networks to embody various constraints. Although Julesz himself produced very early

on (Julesz 1962) a computer-implemented cooperative model, AUTOMAP, that could solve the stereo correspondence problem in certain RDSs, he did not subsequently vigorously pursue computer implementations of his models. He was happiest exploring new phenomena and devising psychophysical tests of his ideas. That style produced the abundance of highly interesting and sometimes seminal papers for which he will be remembered.

I have re-read some of Julesz's review papers by way of preparing this tribute. I have been impressed by what a good read they remain. For example, Julesz and Schumer (1981) remains an excellent summary of work on early visual perception at that time. I would still recommend it to any postgraduate as a useful starting point for getting to grips with what came later. Also, I ask readers to bear in mind that in writing this personal tribute I have concentrated on those aspects of Julesz's research most closely associated with my own time working with him. I have not attempted a full review or a full critique of his extensive contributions.

To repeat, I have very warm memories indeed of Bela Julesz. I was inspired by his astonishing RDSs demonstrations to work on stereo for most of my life. He gave me generously of his time and facilities. He was a hugely important helping hand for me at a critical moment. This generosity was matched by that given to many others. Long may the field cherish his memory via his diverse and creative contributions to the science of perception.

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Bela Julesz, vision researcher and experimental psychologist, was born in Budapest on 19 February 1928. He died suddenly in Warren, New Jersey, on 31 December 2003. He is survived by his wife Margit; they had no children.

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