JACK KIEFER'S CONTRIBUTIONS TO EXPERIMENTAL DESIGN

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1. History. Careful experimentation is part and parcel of the scientific method developed in the eighteenth and nineteenth century. John Stuart Mill was probably the first to give clear prescriptions on how to carry out experiments. He separated experiments into "spontaneous" experiments, what we would now call observational studies, and "artificial" experiments, namely controlled experiments. Mill and others were firmly of the belief that controlled experimentation was better, if the subject matter allowed it. This was carried through into this century with the "crucial experiment" becoming the cornerstone of the falsification ideas of Karl Popper and his followers. The details of experimental strategy, however, were neglected by the philosophers, except that it was recognized that careful variation in the levels of "agents" A, B, C, $\cdots$ would yield an analysis of their effects a, b, c, $\cdots$.

The breakthrough into a more versatile approach to experimental design came with the work of Ronald A. Fisher and his followers, notably Frank Yates, at the Rothamstead Experimental Station in England. A number of useful concepts were introduced such as balance, orthogonality, blocking and aliasing. This led to an explosion of work on combinatorial design which took seed in the USA through the work of Raj Chandra Bose and collaborators.

Here and there in the combinatorial literature the idea of efficiency—usually relative to some standard design—had been discussed. However, at the end of the second world war the theory of optimum design was almost nonexistent except for a remarkable early paper by Smith (1918) and the important paper of Wald (1943). It is no accident that the modern theory of optimum design has its roots in the decision theory school of U.S. statistics founded by Abraham Wald. The idea of "risk," developed formally by Wald and arising out of the earlier work of Neyman and Pearson, was the most important innovation of that school. There were parallel developments in utility theory, mathematical programming and mathematical economics so that the early history of the subjects were interwoven. Together with Wald, Jacob Wolfowitz and Jack Kiefer were leading members of this school. They started the second great advance in the science of experimentation in this century by applying decision-theoretic ideas, and over the subsequent twenty years Jack Kiefer himself nurtured this science to maturity.

2. Continuous theory. Since Wald's paper, a number of papers had appeared by Elfving (1952), Hoel (1958), Guest (1958) and important work by Box and Draper and co-workers on response surface design. Thus, the literature

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