This Week's Citation Classic

The varimax criterion for analytic rotation in factor analysis determines a factor matrix, representing uncorrelated factors, where the variance of the squared loading of a column of the factor matrix is maximized, summed over columns. In a special case the solution is invariant under the addition or subtraction of variables. [The *Science Citation Index®* (*SCI®*) and the *Social Sciences Citation Index™* (*SSCI™*) indicate that this paper has been cited over 725 times since 1961.]

Henry F. Kaiser
School of Education
University of California
Berkeley, CA 94720

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"The varimax criterion was developed in early 1955, when I was a graduate student in education at the University of California, Berkeley. At that time I was supposed to be studying for that awful anachronism, the Ph.D. qualifying examination in German.

"I had earlier developed the quarti-max criterion, but was 'scooped' in publication by Carroll;[1] Wrigley and Neuhaus;[2] Saunders;[3] and Ferguson.[4] What was wrong with the quartimax criterion as a mathematical explication of Thurstone's simple structure was soon apparent: it applied the criterion to the rows of the factor matrix when what should have been done was to apply the criterion to the columns of the factor matrix. This produced varimax. It was originally developed from Carroll's point of view, and thus would have been dubbed 'covarimin,' but it was not obvious that the method would converge computationally in this form. More personally, I was miffed at Carroll, who did not answer my letter about what I had done, while Professor Wrigley, whose lead I ultimately followed, was most generous in correspondence.

"Not being good at mathematics, I was aided in the development by a simple computational paradigm I had devised for Jacobi's method for the algebraic eigenproblem, with which I needed only simple 13th grade calculus.

"Saunders suggested that the criterion should be applied to a factor matrix in which the rows had been normalized. This was crucial, for it gave better results subjectively, and, more importantly, allowed me to prove a theorem regarding the invariance of the varimax solution under the addition or subtraction of variables in a simple case. This invariance theorem is overlooked by those who use varimax. Its widespread use comes primarily from its almost always giving 'nice' results from the viewpoint of scientific interpretability.

"In succeeding years I have tried to improve varimax, without success. Most of these efforts have been 'trans-varimax,' to use Saunders' terminology. Varimax is robust under overfactoring while trans-varimax solutions are not, and the number of factors in a factor analysis seems to defy a definitive solution.

"Varimax has been a tough act to follow. It was my first paper, and none of the more than 100 papers I have written subsequently has had nearly the impact."

1. **Carroll J B.** An analytical solution for approximating simple structure in factor analysis. *Psychometrika* **18**:23-38, 1953.
2. **Neuhaus J O& Wrigley C.** The quartimax method: an analytical approach to orthogonal simple structure. *Brit. J. Statist. Psychol.* **7**:81-91, 1954.
3. **Saunders D R.** An analytic method for rotation to orthogonal simple structure. Princeton. NJ: Educaitoual Testing Service Research Bulletin No. 53-10. 1953.
4. **Ferguson G A.** The concept of parsimony in factor analysis. *Psychometrika* **19**:281-90, 1954.