as measures of stimulus magnitude $[P_x(i) > P_y(i)]$.

If we substitute $a(P_x(i)+c)^b$, that is, the listener's power function for $l_l(x)$ in Eq. 2, we obtain the following linear equation with zero intercept

$$\log\,[P_l\{x,y\}/P_l\{y,x\}] = b \log\,[(P_x(i)+c)/(P_y(i)+c)], \quad (3)$$

where $P_l\{x,y\}$ is the probability that a listener chooses x as the referent in an x-y pair and $P_l\{y,x\} = 1 - P_l\{x,y\}$. Figure 3 is a plot of the empirical relation between listeners' choice data and word-association data $(P_x(i) \geqq P_y(i))$ in which the log transformations in Eq. 3 are used and $c = .0018$ (obtained from a modified least-squares procedure). The fitted straight-line has a slope of .700, that is, the value of b also obtained from the least-squares procedure. The linear fit is particulaly good; there is no indication of any systematic curvilinearity in the observed relationship.

In conclusion, the results of the empirical studies indicate that the stochastic theory described in this paper can provide a satisfactory account of speaker and listener behavior in the communication task. The theory can be generalized, without difficulty, to studies in which a speaker and a listener are given more than one nonreferent and, possibly, to studies in which nonverbal stimuli are assigned as referent and nonreferent(s). The listener theory can also be generalized to studies in which speaker-responses given to a listener consist of phrases and sentences rather than single words.

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References and Notes

1. R. Brown, *Words and Things* (Free Press, Glencoe, Ill., 1958); J. R. Kantor, *An Objective Psychology of Grammar* (Principia, Bloomington, Ind., 1952); C. Morris, *Signs, Language and Behavior* (Prentice-Hall, New York, 1946); C. K. Ogden and I. A. Richards, *The Meaning of Meaning* (Harcourt, Brace, New York, 1948).
2. W. S. Torgerson, *Theory and Methods of Scaling* (Wiley, New York, 1958), pp. 201–203.
3. R. D. Luce, *Individual Choice Behavior* (Wiley, New York, 1959), pp. 20–28.
4. Figure 2 is based on 144 word-triples rather than all 256 since, for fixed values of $P_y(i)$ larger than those shown in Fig. 2, the number of $P_x(i)$ values available in word-association data was insufficient for plotting detailed curves over an adequate range of $P_x(i)$. However, since any combination of $P_x(i)$ and $P_y(i)$ values can be substituted into Eq. 3, the data in Fig. 3 are based on all word-triples. The 112 word-triples not usable in Fig. 2 were selected so as to obtain a wide range of values of $P_x(i)$ and $P_y(i)$.
5. Supported in part by a grant from the Rutgers University Research Council and NSF grant GS-179 to one of us (B.D.C.). This is a preliminary report of this research. We thank Claire Hammond, Meyer Rothberg, and Pathe Vivekananthan for assistance in collecting and processing the data.

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Creative Scientists of Today

Abstract. *To investigate traits differentiating highly creative research scientists from less creative ones, a questionnaire was sent to 740 male scientists (400 chemists and 340 psychologists). Half of each group had achieved eminence as research scientists; the other half had not achieved research eminence, but were matched on relevant variables. Results indicated that creative scientists are more dominant than less creative ones, that they have more initiative, and are more strongly motivated toward intellectual success.*

In this report we are mainly concerned with the differences in personality and biographical factors between mature scientists who are highly creative in research work and those who are much less creative. Previous studies most pertinent to this investigation are those conducted by Roe (*1*) and Cattell and Drevdahl (*2*), in which highly creative scientists were chosen as the subjects for study. Whereas Roe selected a small number of men (64) and used personal interviews and projective techniques, Cattell and Drevdahl chose to use a larger number of subjects and to depend on an objective pencil-and-paper test of personality. Roe's major finding was that the men were very strongly motivated—that is, they were willing to work hard and for long hours. Cattell found his scientists to be cool and aloof, dominant, and introspective. A general summary of studies in this area may be found by consulting Taylor and Barron (*3*).

In this current study attempts were made to improve on the previous studies of creativity by using larger samples of subjects, by using control groups matched on the variables of sex, age, education, discipline, and opportunity to do research, and by using measuring instruments which have had the variables they purport to measure anchored by validity studies to ultimate criteria (real-life situations).

The subjects used were U.S. male scientists, 400 chemists and 340 psychologists. Within each profession, half were chosen on the basis of having achieved eminence as research scientists, as recognized by membership in the National Academy of Sciences or the American Philosophical Society, being starred in *American Men of Science*, or similar evidence of national recognition of research contributions; the other half were chosen from the membership lists of professional societies of the discipline, and each individual in the lower half was chosen to match an individual in the upper half on the bases of age, sex, discipline, amount of education, and opportunity to do research. None of the members of the lower half of either group had achieved eminence or had been noted for having produced research work of any great value. The productivity of the scientists (number of publications), however, did *not* serve as one of the criteria for admission to either the highly creative or control groups.

For the major study (*4*) an 81-item biographical inventory (*5*) was used to obtain information concerning personal data; job-related behavior and attitudes; undergraduate, secondary, and primary schooling; and home life in childhood and youth. Also used for the study were factors *E* (dominance), *F* (enthusiasm), *H* (adventurousness), and Q_2 (self-sufficiency), from Cattell and Stice's 16 Personality Factor Questionnaire (*6*); items 51 to 75 from Maslow's Security-Insecurity Inventory (*7*); and the Initiative Scale from Ghiselli's Self-Description Inventory (*8*). The items were reproduced in the form of a printed questionnaire and mailed to each subject. A total of 438 forms, or approximately 60 percent, was returned usable. The characteristics of the various groups and of the total sample in relation to number of doctorates, age, and type of employment are shown in Table 1.

Two major findings in the personality tests (Table 2) were: (i) creative scientists are more dominant than control scientists (higher mean *E* score); and (ii) they have more initiative (higher mean score on the Ghiselli scale). Neither the 16 Personality Factor for measuring creativity nor any other scale differentiated between creative and control scientists.

Significant differences were found for 16 biographical items. Specifically, the creative scientists more often had fathers who were professional men. They

Table 1. Doctoral degrees, age, and employment of subjects (EP, Creative psychologists; CP, control psychologists; EC, creative chemists; CC, control chemists; P, all psychologists; C, all chemists).

Group	Total	No. of doctoral degrees	Median age of group	Employment				
				Educational	Industrial	Governmental	Other	Not listed
EP	110	109	49.5	99	4	4	3	0
CP	103	102	50	89	2	10	1	1
EC	108	104	56	75	20	8	3	2
CC	117	116	54	110	6	1	0	0
P	213	211	50	188	6	14	4	1
C	225	220	55	185	26	9	3	2
Total	438	431	53	373	32	23	7	3

graduated from high school at a younger age than control scientists, and, later, more often achieved a straight A average both as undergraduate and graduate students. They spent many more hours per week (in excess of 50) on study and research while in graduate school, published more articles then, and more often had their graduate school expenses met through scholarships and fellowships than by part-time work.

As mature scientists, the creative men still show this strong motivation. They read more professional journals and present more papers at conventions. They produce many more articles than the control scientists.

Several factors unrelated to ability and motivation also discriminated between the two groups. The highly creative men in their lives today significantly more often show either no preference for a particular religion or little or no interest in any religion; they also have few or no commitments to civic or community affairs. Of possible interest to employers of research personnel was the finding that, when seeking a position, the less creative scientists are predominantly concerned with opportunities to combine teaching and administrative duties with research, while the overwhelming choice for the creative scientists is the opportunity to do really creative research and to choose problems of interest to them.

The findings described so far were common to both psychologists and chemists, but creative psychologists differed from control psychologists in other ways not found with chemists. Creative psychologists proved to be more self-sufficient than their controls (factor Q_2). There were also significant differences on four more biographical items, indicating that: (i) creative men in this profession more often came from individualistic families in which each person went his own way; (ii) the creative man chose research as a career at a younger age than his less creative contemporaries; (iii) creative psychologists placed less value on professional conventions than their controls despite the fact that they presented more papers; and (iv) creative psychologists derived much more satisfaction from their work than their less creative peers.

Creative chemists differed from their controls on ten more biographical items (there were no differences in the other tests). These items indicated that even in childhood the creative chemists displayed differences in achievements and feelings as compared with the less creative chemists. The creative chemists were usually the middle or older children in a family. At relatively early ages these children considered their families to be superior to others. In high school the creative children exhibited their strong intellectual orientation by shunning sports and excelling in mathematics. This intellectual ability and motivation continued through undergraduate school when they became members of many honor societies and graduated at an early age. As adults these creative chemists are still exhibiting this exceptionally strong intellectual drive, now channeled into professional activities as evidenced by their membership in many professional organizations and attendance at many professional conventions, as well as by their spending long hours each week at work. Further, many more of these men than their controls believed that 40 hours or more per week should be spent in active research if creative output was to be at a maximum.

The creative scientist thus emerges as a strongly motivated, dominant person who is not overly concerned with other persons' views or with obtaining approval for the work he is doing (biographical factors and factors E and Q_2). He is not the type of person who waits for someone else to tell him what to do, but rather thinks things through and then takes action on his own, with little regard to convention or current "fashion" (Initiative Scale and factor Q_2). He then is prepared to face the consequences of making unpopular decisions or of pursuing unconventional paths in his search for evidence relating to nature's laws (factors E and Q_2).

This study throws some light on the relation between mental health and creativity. Several investigators have been outspoken in their insistence on there being a relation between these two concepts. Rogers (*9*) and Maslow (*10*), for example, have stressed "openness to experience" or "self-actualization" as basic for creativity, with both of these terms apparently referring to positive mental health, or extremely well-adjusted behavior. On the other hand, Roe (*1*) pointed out that many of the highly creative scientists she studied were experiencing rather severe emotional problems, and she therefore hypothesized that basic insecurities were possible sources of the strong motivation to succeed in the lives of these persons. Mead (*11*) also indicated a correlation of schizophrenic-like behavior with highly creative artistic productivity, and well-adjusted "happy" behavior with

Table 2. Comparison of creative and control psychologists and chemists based on personality tests. All average (Av.) scores represent means; all variance (Var.) measures are standard deviations (N varies from 213 to 225).

Factor*	Psychologists					Chemists				
	Creative		Control		*t*-test	Creative		Control		*t*-test
	Av.	Var.	Av.	Var.		Av.	Var.	Av.	Var.	
E	14.98	3.27	13.92	3.48	2.34†	14.15	3.52	12.91	3.89	2.53†
Q_2	13.63	2.60	11.92	3.35	4.14†					
Gh	34.44	6.68	28.06	7.68	6.63†	33.18	8.14	29.38	7.79	3.66†

* Factors E and Q_2 refer to dominance and self-sufficiency, respectively, from Cattell's 16 Personality Factor Questionnaire. Factor *Gh* refers to a measure of initiative from Ghiselli's Self-Description Inventory. † $p < .05$.

low-level creative artistic productivity, in her cultural studies in the South Pacific. Historical studies of some highly creative artists also reveal a high incidence of neurotic or psychotic-like behavior among these persons.

The Maslow Security-Insecurity Inventory was included in this study in order to investigate this problem, and all groups were classified in the "average" range on Maslow's norms. Regarding his test, Maslow stated that "the purpose of the Security-Insecurity Inventory is to detect and measure the feeling of security (which as defined here is one of the most important determinants of mental health, almost to the point of being synonymous with it) . . ." (*7*, pp. 2–3), and again ". . . security as defined here is almost synonymous with mental health . . ." (*7*, p. 7). If Maslow's definition is accepted, the present results certainly offer no support for Roe's hypothesis or for the implications of Mead's studies in relation to creativity in science. These findings give little support to the hypothesis that creativity is associated with the highest level of mental health (degree of personal adjustment), since the average scores for the groups were not in the "very secure" range, but rather were only "average."

The religious factor, also, is of interest here. It has usually been found that creative scientists show a preference for the Protestant religion and that very few eminent scientists prefer Catholicism. This was noted by Roe (*1*), Knapp and Goodrich (*12*)—in relation to the production of scientists by Catholic institutions of higher learning—and by others. This report therefore supports Knapp and Goodrich's findings in that only 1½ percent of all scientists included in the study attended undergraduate schools with Catholic affiliation. Further, only 6 percent of all subjects came from homes in which the Catholic faith was preferred, while 77 percent came from Protestant homes. However, no relation was found between the achievement of creative status and religious preference. It appears, then, that religious preference is much more strongly associated with the choice of science as a career than it is with achievement of highly creative productivity within a scientific discipline.

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References and Notes

1. A. Roe, *Psychol. Monogr.* **67**, No. 352 (1953).
2. R. Cattell and J. Drevdahl, *Brit. J. Psychol.* **46**, 248 (1955); J. Drevdahl and R. Cattell, *J. Clin. Psychol.* **14**, 107 (1958); R. Cattell, in *The 3rd (1959) University of Utah Research Conference on the Identification of Creative Scientific Talent*, C. W. Taylor, Ed. (Univ. of Utah Press, Salt Lake City, 1959), pp. 77–93.
3. C. Taylor and F. Barron, Eds., *Scientific Creativity, Its Recognition and Development* (Wiley, New York, 1963).
4. J. A. Chambers, *Psychol. Monogr.*, in press.
5. Developed by J. A. Chambers.
6. R. Cattell and G. Stice, *The 16 Personality Factor Questionnaire* (Institute for Personality and Ability Testing, Champaign, Ill., 1957).
7. A. Maslow, *Manual for the Security-Insecurity Inventory* (Consulting Psychologists Press, Palo Alto, Calif., 1952).
8. E. Ghiselli, *Personnel Psychol.* **7**, 201 (1954); *ibid.* **8**, 157 (1955).
9. C. Rogers, in *Creativity and Its Cultivation*, H. H. Anderson, Ed. (Harper, New York, 1959), pp. 69–82.
10. A. Maslow, *ibid.*, pp. 83–95.
11. M. Mead, *ibid.*, pp.222–235.
12. R. Knapp and H. Goodrich, *Origins of American Scientists* (Univ. of Chicago Press, Chicago, 1952).
13. Supported by a grant from the James McKeen Cattell Foundation.

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Human Cones

I was greatly pleased with the magnificent experimental results on visual pigments recently published (*1*). Although the maximum density values for cones are similar to those obtained by fundus reflectometry in the gray squirrel (*2*)—the first living cone retina to yield a result comparable with recent measurements—they seem somewhat low when compared with data obtained by this method on living, intact foveal human cones. Double passage through the retina gives in this case $\Delta D_{\max} \doteq 0.2$ (*3*). Brown and Wald's values (*1*) are, as the authors point out, much too low when compared with Rushton's recent measurement (*4*). However, two points have to be made in this connection. First, the authors examined what appears to be a normal retina, whereas Rushton dealt with a protanope. Second, Rushton's value of 0.35 is wholly inconsistent with other data he published in the same series (*5*). He claims to obtain good agreement between his difference spectrum and Pitt's spectral-sensitivity (S) curve (*6*), which he did not correct for preretinal absorption losses. But if the density in protanopic cones is as high as he estimates it to be (on the basis of a theory that is unclear to at least one reader), then the S-curve ought to be much broader, as shown in Fig. 1 (*7*)—preretinal losses being ignored also in this curve for the sake of consistency. It can be shown that much of Rushton's third paper (*8*) in this series—notably his conclusions regarding photosensitivity and also the relation between pigment regeneration and dark adaptation—are invalidated (*7*) by the inconsistency between the second and first papers.

The reason is clear. The computed value of σ, believed by Rushton (*5*, p. 371) to represent the fraction of stray light, is numerically linked to the high density value of 0.35. He writes: "Though 0.35 might seem rather a high value for cone density, it would have come out a great deal higher if the stray light factor σ were not as small as 2.0." Thus if Rushton's theory is valid and his measurement correct, σ must be smaller and his claim to have made it low by attention to instrumental design a modest understatement. Now Rushton's two comparisons—(i) between predicted and computed values of the intensity variation of the fraction of pigment bleached, and (ii) between the fraction of pigment regenerated as a function of time and the course of dark adaptation—show fairly good agreement (but see *7*). However, the computed values that these coincident pairs of data are based on are derived by means of a nomogram pinpointing the above value of σ. It might be deduced that the value of σ is not of great importance, but it

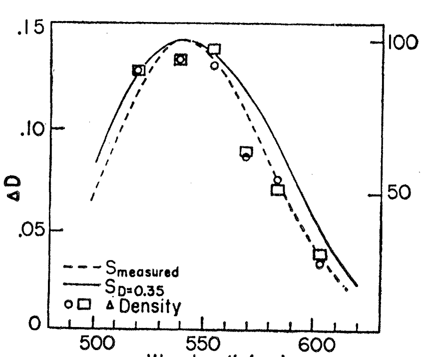

Fig. 1. The solid line indicates the shape of the protanopic V_λ curve if Rushton's density value of 0.35 is correct. The broken line is Pitt's curve.