SOME CORRELATES OF TECHNICAL AND SCIENTIFIC PRODUCTIVITY

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GARDNER Murphy (3, p. 479) defines *creativeness* as *"The capacity to produce through thought or imagination; capacity for original work."* Since he devotes an entire chapter to a survey of research on the creative personality, no attempt to review the literature is attempted here. However, the relevant literature reveals a need for more quantitative research on the creative personality. Existing literature is dominated by either anecdotal reports or by well-defined and intensive studies of single traits such as age (2).

The research which follows is an attempt to add insights into the creative personality by studying simultaneously twelve variables for their causal or artifactual relationships to scientific and technical creativeness.

Experimental Design

An information sheet was prepared and mailed to all 467 scientific and technical personnel of the Illinois Institute of Technology and Armour Research Foundation. The information sheet (see Table 1) contains nine points of objective information and three attitudinal queries—including degrees, rank, age, inventions and publications, professional affiliations, number of relevant journals read, homework hours, regimented hours, workplace hours and certain attitudes toward conduct of research.

The Subjects

A total of 194 responses (42 per cent) were received, representing 147 members of the faculty and 47 scientific personnel of the Armour Research Foundation. Of these 194 respondents, 91 possess the Ph.D. degree, 67 the M.S., and 36 the B.S. as their highest degree. Median age for the group is 34.9, with a range from 20 through 65. The median respondent belongs to 4.4 honorary and professional organizations, reads 5.5 scientific, professional, or technical journals, reports devoting 4.2 hours per typical workday to job-related homework, reports obligation to perform 21.7 hours per week of specified ("regimented") duties at a specified place, and reports actually spending 43.5 hours per week on the academic and work premises.

The independent evidence of distribution of degrees, rank, and age indicates that this sample of 42 per cent probably is a reasonably random sample of total technical and scientific personnel.

The Criterion

Best measures of the initiative and creativity of these personnel were believed to be inventions and publications, since these are objective indices. Some scientific and professional workers have no inventions but produce publications (47 per cent of sample) which contain new ideas which operationally are equivalent to inventions; some workers produce inventions but no publications (3 per cent of these personnel); others produce both inventions and publications (34 per cent); and still others produce neither (16 per cent).

In order to combine these two indices of productivity into a single measure of productivity, publications and inventions were equated and then combined for each individual. Since for the total group there were approximately five times as many publications as inventions, the number of inventions for each individual was multiplied by five and to this product the number of publications was added, and the result was employed as the individual's measure of productivity. In the absence of data as to which is more valuable, inventions or professional publications, the authors by this procedure weighted each equally.

Results

The last three items on the information sheet are attitudinal questions intended to obtain data on the motivational orientation of scientific and technical personnel.

When asked to rank three methods of executing a research project, the respondents assigned the following percentages of first choices: 62—one person initiating and conducting research with broad freedom in selecting assistants; 14—any person in stable research group initiating, but group conducting and sharing equally in project; and 24—any person in stable research group initiating, but group conducting, and each member sharing according to value of contribution.

In order to obtain some estimate of the reaction of these personnel to an aspect of work regimentation, they were asked to rank the "following alternatives in the order in which you perform your best work." Their percentages of first choices are as follows: 23—when faced with deadline your supervisor set; 51—when faced with deadline you

TABLE 1

BRIEF WORK BALLOT

1. I am a member of: Faculty.....; ARF.....
2. Degrees held: Bachelor's.....; Master's.....; Doctor's.....
3. If Faculty member please indicate rank:
   Administrator.....; Professor.....; Associate Professor.....; Assistant Professor.....; Lecturer.....; Instructor.....
4. Age: (encircle closest figure)
   20 25 30 35 40 45 50 55 60 65
5. How many publications are in your bibliography? .....
   How many *inventions* are you in part *responsible for*? .....
6. To how many honorary fraternities do you belong? .....
   To how many professional organizations do you belong? .....
7. How many different scientific, professional or technical journals do you read? .....
8. How many hours per typical work day do you devote to home work which contributes to the efficient performance of your job? .....
9. How many hours per week are you required to perform a specific duty at a specific place? (e.g., lecturing, ARF research, lab supervision, etc.) .....
10. How many hours per average week do you actually spend on campus? .....
11. Below are 3 methods for executing a professional or technical research project. Rank them in order according to your own opinion with 1 for most efficient and 3 for least efficient.
    ....a) any person *in stable research group initiating but group conducting and sharing equally in project.*
    ....b) any person in stable research group initiating but group conducting and each member sharing according to value of contribution.
    ....c) one person initiating and conducting research with broad freedom in selecting assistants.
12. Rank the following alternatives in the order in which you perform your best work.
    ....a) when faced with deadline your supervisor set.
    ....b) when faced with deadline you yourself set.
    ....c) when faced with no specific deadline.
13. Rank the following alternatives in the order in which you are stimulated to do your best work.
    ....a) when an immediate economic gain is in prospect for you.
    ....b) when immediate economic gain for your organization is in prospect.
    ....c) when you feel you are accomplishing something that is "good."

TABLE 2

TABULATIVE SUMMARY AND BASIC STATISTICS OF PRODUCTIVITY RESEARCH DATA (N=194)*

VARIABLE	MEAN	S.D.	PER CENT
Faculty			76
Armour Research Foundation			34
Bachelor's Degree			18
Master's Degree			35
Doctor's Degree			47
Administrator			10
Professor			24
Associate Professor			20
Assistant Professor			23
Lecturer			6
Instructor			17
Age	38.4	9.7	
Publications	10.5	23.9	
Inventions	2.3	14.6	
Weighted productivity	22.0	11.3	
Honorary and professional organization memberships	5.1	2.9	
Relevant journals read	5.9	12.9	
Relevant homework per day in hours	3.0	1.5	
Regimented work hours per week	23.7	13.7	
Total general workplace hours	37.8	11.5	

* Percentage replies on the three attitudinal questions are reported under "Results" in text.

TABLE 3

INTERCORRELATIONS * AMONG SCIENTIFIC AND TECHNICAL PRODUCTIVITY AND CERTAIN OTHER VARIABLES (N=194)

	1a	1b	2	3	4	5	6	7	8a	8b	9	10	11	12
1a. Publications and inventions														
1b. Publications and inventions with age held constant by partial r's														
2. Degrees held	*.52*	*.41*												
3. Rank	*.48*	.16	*.65*											
4. Age	*.56*		*.36*	*.67*										
5. Honorary and professional organizational memberships held	*.32*	.18	*.36*	*.46*	*.35*									
6. Journals read	*.38*	*.26*	*.61*	*.46*	*.36*	*.51*								
7. Homework hours	.11	—.06	.02	.16	.29	.29	*.63*							
8a. Total regimented hours	.18	.12	*—.30*	*.35*	—.16	*—.39*	*.32*	*—.44*						
8b. Regimented hrs. with 40 hr./wk. group excluded (N=152)	—.07	—.10	*—.34*	—.09	.01	—.19	.03	*—.30*						
9. Workplace hours	—.20	—.19	.27	*.26*	—.10	.05	*.52*	*—.36*	*.40*	.05				
10. Belief in equalitarian practices in research groups	*—.41*	*—.75*	—.04	—.01	*.32*	.05	—.07	*.26*	*.42*	*.34*	*—.31*			
11. Favors voluntary determination of deadlines	*.48*	*.57*	—.03	—.09	.02	*.20*	*.05*	.08	—.04	—.10	.04	—.12		
12. Selflessness of motive	*.28*	*.15*	*.37*	—.01	*.18*	*.08*	*.40*	*—.37*	*—.37*	*—.50*	*—.44*	*.16*	*.37*	

* Tetrachoric coefficients of correlation which are statistically significant at the 5 per cent level or better according to Kelley's tetrachoric reliability formula and the Guilford-Lyons tables (1) are indicated in italics.

yourself set; and 26—when faced with no specific deadline.

Asked to rank three incentives "in the order in which you are stimulated to do your best work," these percentages of first choice resulted: 8—when an immediate economic gain for your organization is in prospect; 19—when an immediate economic gain is in prospect for you; and 73—when you feel you are accomplishing something that is "good."

The authors regard the latter alternative as the "selfless" half of an arbitrary "selfish-selfless" motivational continuum.

Measurements on the criterion variable, the attitudinal variables, and each of the objective variables were intercorrelated in order to explore further the dynamic interrelationships of productivity with other variables. These coefficients of correlation, shown in Table 3, constitute a matrix which also includes a special "regimented hours" variable (No. 8*b*) on which reports of the 40-hour regimented group (42 respondents) is omitted deliberately, since it is the only constituent subgroup in the total sample which lacks freedom in assignment of place for its hours of work. Also added to the matrix (variable No. 1*b*) is a row of partial correlations—the relations of productivity with the other variables when age of respondent is held constant.

DISCUSSION

A majority of the variables studied in this analysis are significantly related to the scientific and technical productivity of the 194 persons in the sample. Ignoring the age factor, the *high producer* has more degrees, higher rank, more honorary and professional memberships, more journals read, less belief in equalitarian practices in research units, more belief in voluntary determination of deadlines, and more selflessness of motive. The possible causal significance of some of these findings is negated because of the contamination of several of the variables with the age factor. Age correlates .56 with the productivity criterion.

When age is held constant, three variables still survive as significant correlates of scientific and technical productivity; these are: (1) degrees held, (2) disbelief in equalitarian practices in research groups, and (3) belief in voluntary determination of deadlines.

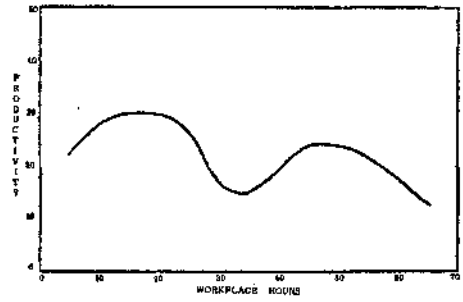

FIG. 1. RELATIONSHIP BETWEEN PRODUCTIVITY AND GENERAL WORKPLACE HOURS OF 194 SCIENTIFIC AND TECHNICAL PERSONNEL

These results, at least for this sample, tend to suggest that the high scientific and technical producer holds the Doctor of Philosophy degree (or stated perhaps more operationally, is technically competent), favors the competent person's being assigned responsibility for initiating and conducting research, and favors considerable latitude of freedom in working hours, etc. The latter two conclusions strongly point toward the high technical producer as an individualistic type of personality with a fundamental dislike for regimentation.

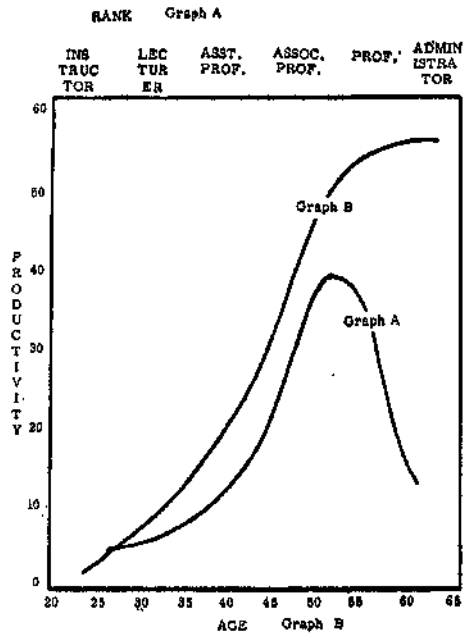

FIG. 2. RELATIONSHIPS BETWEEN PRODUCTIVITY AND AGE (Graph A) AND BETWEEN PRODUCTIVITY AND RANK (Graph B) OF 194 SCIENTIFIC AND TECHNICAL PERSONNEL

Certain relationships which arbitrarily were computed under the rectilinear assumption actually were curvilinear. These relationships are displayed graphically in Figs. 1 to 5.

Figure 1, illustrating the relationship between productivity and hours actually spent at the workplace, suggests decreasing returns with increasing hours, with greatest technical and scientific productivity achieved by indi-

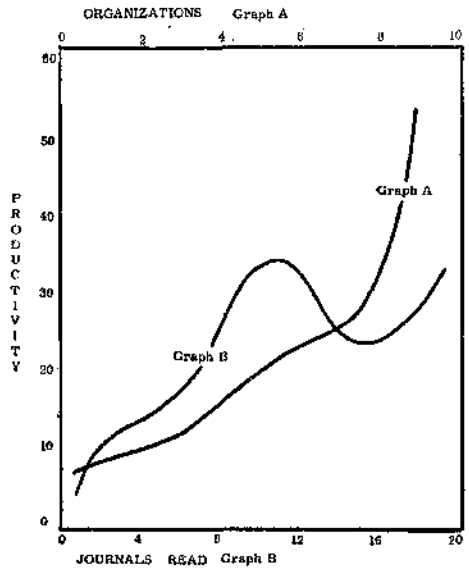

FIG. 3. RELATIONSHIPS BETWEEN PRODUCTIVITY AND HONORARY, TECHNICAL, AND SCIENTIFIC ORGANIZATIONAL MEMBERSHIPS AND BETWEEN PRODUCTIVITY AND RELEVANT JOURNALS READ (N=194)

viduals who spend from only about 10 to 20 hours per week at their campus workplace. This conclusion, which survives when age is held constant, must be qualified by the probability that these persons do much of their creative work at home or elsewhere. A possible explanation of this tendency is the apparently greater individualism of the highly productive personnel. The apparent dip in productivity for persons who invest from 24 to 35 hours at the workplace is difficult to explain, although the authors believe that this may be due to a tendency for less capable individuals—the "pluggers"—who are required to spend only about 15 hours per week at the workplace to spend about

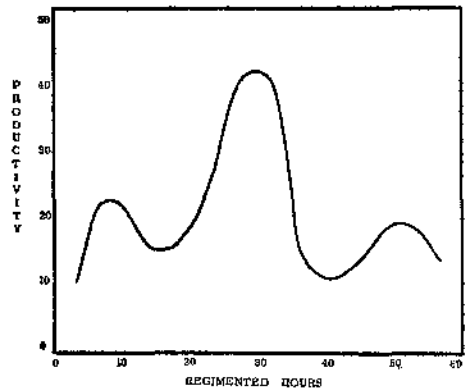

FIG. 4. RELATIONSHIP BETWEEN PRODUCTIVITY AND REGIMENTED HOURS (N=194)

twice the required hours in an attempt to appear "industrious" to their superiors. The minor rise in productivity between workplace hours of 45 and 55 per week is believed to be due in part to the nature of certain types of physical research which requires continuous use of bulky equipment and the continuous—though sometimes inactive—presence of ambitious research personnel.

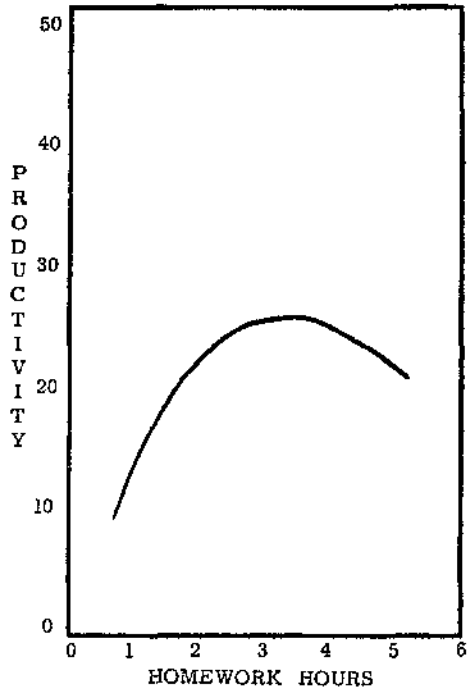

FIG. 5. RELATIONSHIP BETWEEN PRODUCTIVITY AND RELEVANT HOMEWORK HOURS PER DAY (N=194)

Although specific supporting evidence is not available, the authors believe that Fig. 1 would portray a consistently declining curve after "20 workplace hours" if training, selection, and placement of scientific personnel were made rigorous enough to minimize the presence of the "plugger" group.

Accumulated productivity, as shown in Fig. 2, is almost a linear function with age except that successive increments are slight after age 50. Rank and accumulated productivity suggest a similar function except that administrators do not support the general trend.

Honorary and professional memberships and journals read (Fig. 3) apparently bear slight curvilinear but positive relationships with accumulated productivity.

Regimented hours (presence required at specific place on specified functions) bears a marked non-linear relationship to accumulated productivity. Maximal productivity apparently is achieved when regimented hours are approximately 28 per week. Whether this relationship is a causal one is unknown, but 28 hours per week may be the typical optimal compromise between allowance for individualistic creative temperaments and the need for a reasonable amount of work and discipline.

Apparently the high producers tend to put in somewhat greater hours in related "homework" and fewer at official workplace; this too, however (Fig. 5), has optimal limitations. Accumulated productivity increases with increased homework up to 3.5 hours per day, but an increase in homework above 3.5 hours seems to result in decreased productivity.

SUMMARY AND CONCLUSIONS

Using publications and inventions (weighted) as a combined technical and scientific productivity criterion, reports on certain work habits, practices, and attitudes were collected from 194 technical and scientific personnel. Analysis of these reports against the criterion suggested the following conclusions, limited, of course, by the sample and the experimental design.

1. Individuals with greatest accumulated productivity were characterized by more degrees, higher rank, more honorary and professional memberships, more journals read, less belief in equalitarian practices in research units, more belief in voluntary determination of deadlines, and more selflessness of motive.

2. When age is held constant, three traits still survive as characteristic of the more creative individuals: (*a*) degrees held, (*b*) disbelief in equalitarian practices in research groups, and (*c*) belief in self-determination of deadlines.

3. Separate study of certain curvilinear relationships suggests that maximal technical and scientific productivity of these subjects is achieved with optimal conditions of about (*a*) 28 hours per week of regimented hours and (*b*) 3.5 hours per day of related homework.

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