A STUDY OF IMAGERY IN RESEARCH SCIENTISTS*

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The data reported here were gathered in the course of a study of personalities of research scientists as related to vocation The 64 subjects of that study are eminent research scientists in the fields of biology, physics and physical chemistry, psychology and anthropology Most of the men are members of the National Academy of Sciences, or the American Philosophical Society, or both Age range is 31 to 60, with a mean of 47 7 Further data on the sample are given in the full reports (**10, 11, 12**) The research plan included intensive interviews on life history, discussion of their work and working habits, and three tests, the Rorschach, the Thematic Apperception Test, and a special test of verbal, spatial, and mathematical functions

During the first year's work, which dealt with biologists, I slowly became aware that their description of working habits very frequently implied mental processes quite foreign to my own, and it occurred to me that these might have some relevance to the problems under investigation. From then on I made attempts to get definite information on this point, and also checked it with the subjects already visited The results of this part of the study are embodied in this paper

It must be explicitly stated that the raw data on thinking processes are highly unsatisfactory They are introspective reports by subjects of whom few (even among the psychologists) were trained in introspection, in order to get any information at all it was frequently necessary to ask leading questions There are no standardized tests or techniques by which anything in the way of objective evidence can be obtained The justification for this paper lies in the fact that, despite the crudeness of the data, psychologically mean-

* This is part of a study financed by the National Institute of Mental Health of the United States Public Health Service

ingful relations do appear, and in the hope that it will stimulate more research in this area

There have been some tests suggested in this field, none of which is sufficiently worked out or strictly relevant here, and all of which would require more time than could be allotted to this relatively minor part of the study In 1909 Betts (1) studied types of imagery, distinguishing spontaneous and voluntary, and the frequency and clarity of occurrence for seven sensory modalities He found, as have all who have worked with the problem, that most subjects can employ a wider range of imagery than they normally do and that thinking can go on without the intervention of imagery

Griffitts (4 and 5) offered a long series of tests and evidence obtained from these, on incidence of types of imagery, relative clearness and dominance, and so on A major difficulty in all such work is equating intensity ratings of one subject with those of another

Here I have not been concerned with availability to any subject of various types of imagery, or with their clarity or intensity, but rather with the types of imagery which he relied upon when thinking, and specifically when thinking about research problems I made no attempt to check on eidetic imagery, although this, particularly in the case of those who rely largely on visual imagery, would be of considerable interest [1]

This sort of inquiry dates back at least to Galton (3), whose remarks on the subject are worth recalling

> To my astonishment, I found that the great majority of the men of science to whom I first applied, protested that mental imagery was unknown to them, and they looked on me as fanciful and fantastic in supposing that the words "mental imagery" really expressed what I believed everybody supposed them to mean On the other hand, when I spoke to persons whom I met in general society I found an entirely different disposition to prevail The conformity of replies from so many different sources which was clear from the first, the fact of their apparent trustworthiness being on the whole much increased by cross-examination, and the evident effort made to give accurate answers, have convinced me that it is a much easier matter than I had anticipated to obtain trustworthy replies to psychological questions Here, then, are two rather notable results the one is the proved facility of obtaining statistical insight into the processes of other person's minds . . and the

[1] Nor have I reviewed the eidetic literature since Kluver's 1932 summary of it (6) It would be possible to make some limited comparison but meaningful ones would require a complete recasting of my data on personality

other is that scientific men, as a class, have feeble powers of visual representation There is no doubt whatever on the latter point, however it may be accounted for My own conclusion is, that an over-ready perception of sharp mental pictures is antagonistic to the acquirement of habits of highly generalized and abstract thought, especially when the steps of reasoning are carried on by words as symbols, and that if the faculty of seeing the pictures was ever possessed by men who think hard, it is very apt to be lost by disuse The highest minds are probably those in which it is not lost, but subordinated, and is ready for use on suitable occasions

In what particular field of science his scientific subjects worked is not clear, but my data would indicate that this is important I suspect Galton himself had acute visual imagery, for in spite of his suggestion about the "highest minds" he goes on to plead eloquently for the further development and utilization of visual imagery

There can, however, be no doubt as to the utility of the visualizing faculty when it is duly subordinated to the higher intellectual operations A visual image is the most perfect form of mental representation wherever the shape, position and relations of objects in space are concerned The pleasure its use can afford is immense Our bookish and wordy education tends to repress this valuable gift of nature A faculty that is of importance in all technical and artistic occupations, that gives accuracy to our perceptions, and justness to our generalisations, is starved by lazy disuse, instead of being cultivated judiciously in such a way as will on the whole bring the best return I believe that a serious study of the best method of developing and utilising this faculty, without prejudice to the practice of abstract thought in symbols, is one of the many pressing disiderata in the yet unformed science of education

In 1927 a group of British psychologists discussed the relevance of visual imagery to the process of thinking (8) without coming to any general conclusion, but the discussion points up the difficulties of conveying an understanding of, e g , visualizing, to a person without facility in the process

I asked my subjects in what form thoughts were handled by them Usually this had to be expanded and then I asked specifically about their use of visual imagery, and if it appeared that they used it, whether it was concrete, diagrammatic or otherwise symbolic, three-dimensional, freely manipulable, etc An example of such a report is

I believe that I think in visual images of the object under consideration, in 3 dimensions in patterns I could say that my imagery consists probably of a composition of the plants I've seen, the diagrams I've seen I see a forest in my mind and the sand and the clay In thinking on theo-

retical problems, it's again a succession of visual images I even conjure up mental pictures of the Cretaceous and Tertiary and watch how they change

I also inquired specifically about verbal imagery, which was consistently auditory or auditory-motor, and which was usually described in such terms as, "It comes awfully close to talking to myself most of the time" Some of the subjects, particularly theoretical physicists, rely heavily upon symbolic thinking which is related to, but not strictly, verbal thinking in auditory or auditory-motor terms

I then also inquired about their use of imageless thinking in cases where no reference to this process had been spontaneously included in their report When specific imagery as accompaniment to thinking was denied, I subsumed under this heading such descriptions as the following (there is, to be sure, a hint of kinesthetic involvement in some of the reports, but it is not at all clear whether this is really sensory rather than imaginal, there may likewise be accompanying visceral sensations, I think) "I just seem to vegetate, something is going on, I don't know what it is", "I often know intuitively what the answer is, then I have to work it out", "it's a feeling of relationships" A number of the psychologists spoke of kinesthetic imagery as important, I could not determine whether this was actually distinct from imageless thinking as the term is used here

When subjects who primarily use other forms are faced with the problem of communicating their findings, they will then of necessity make use of some verbal imagery I have not credited them with verbal imagery on this account alone, nor have I included as users of verbal imagery those who say they can construct visual images (as most do claim) but who practically never construct them, so far as they are aware [2] Categorization of the data thus

[2] It occurred to me that it might be easier to get information on hypnagogic imagery, and that it was worth checking whether this seemed to be the same type of imagery as that used during waking hours This information is also difficult to get, but such data as I obtained would indicate greater use of visual imagery in this stage than in any other, even among those who do not employ it to any extent while fully conscious On the other hand there are a number of subjects who insist that at such periods it is a "jumble of words" that goes through their minds, these subjects are mostly verbalists There are others who describe considerable action The relation to waking imagery is not clear, and seems to me a point worth further investigation

obtained was very difficult, but the scheme followed here seemed to be the best for the material treated.

Imagery and Scientific Field

In Table I, each of 61 scientists (there were 64 in the total group studied, but adequate data on imagery were not obtained from three of them) is listed under every heading to which some statement about his thinking is relevant The code letters used in designating each man refer to his special field, according to the scheme given on the Table, the numbers are arbitrarily assigned In the interest of anonymity I have not further subdivided the anthropologists

A pattern emerges clearly from the table The biologists are concentrated in the visual imagery group So are the experimental physicists, while the theoretical physicists more characteristically employ verbal or other symbolizations The psychologists and anthropologists are heavily concentrated in the verbal group (this includes all of the cultural anthropologists) That fewer biologists are recorded as using imageless thought in addition to imagery may be due to less adequate inquiry on this point among them—they were the first group studied I feel quite sure that imageless thought, to varying degrees, is almost certainly utilized by most of these men Use of it is so frequently combined with use of some type of imagery that it seems justifiable to make the categorization shown in Table II

Table II[3] summarizes the data of Table I in larger categories Subjects A2, P1, PG1, TP1, E5, Ps3 and Ps9 are not included, since they use rather uncommon combinations The association shown in the table is statistically significant It cannot be deduced from this whether possession of appropriate imagery is conducive to choice of vocational field or whether work in the field tends to develop a particular type There are some suggestions in the material that follows which would lend greater weight to the former supposition, but the question is clearly open

I would like to suggest also, and very tentatively, that the subjects who do not follow the imagery pattern most typical for their own group are also somewhat less like their colleagues in their work and personalities Since all of these men have made original

[3] All calculations were done by Mr Lassar Gotkin

TABLE I

MENTAL PROCESSES UTILIZED BY SUBJECTS

	Visual Imagery						
	Concrete, usually 3-dimensional	Diagrams, geometrical, etc	Symbols, Visualized	Formulae, etc Verbalized	Verbal Imagery (auditory-motor)	Imageless Thought (variously described)	Kinesthetic (not otherwise described)
Biologists	A2 A3 P1 P2 P3 PG2 PG3 PPG4 ZG1 B2 B3	PG2 PG4 ZG4	PG1 ZG4 B3		A2 P1 P5 ZG2 ZG3 B1	A1 P4 PG1 ZG2 ZG4 B3 B4	
Physicists	EP3 EP4 EP5 EP6 EP7 EP9 EPC3 TP3 TP9 TPC4	EP3 EP9 EPC3 TP3 TPC4	EP4 EP5 EPC3 TP7 TPC4	EP5 TP4 TP6 TP9	TP4 TP5 TP6 TP8	EP1 EP3 EP6 EP7 EP8 EPC3 TP1 TP6 TP8 TPC1 TPC2 TPC4	
Psychologists and Anthropologists	EPs5 EPs9 An6			EPs3	EPs1 EPs4 EPs6 EPs9 CPs10 CPs11 An1 An2 An3 An4 An8	EPs1 EPs2 EPs3 EPs4 EPs6 EPs7 EPs8 CPs11 CPs12 CPs14 An1 An3 An4 An5 An8	EPs8 EPs9 CPs10 CPs14

Legend

A	anatomy physiology An anthropology
P	botany
PG	botanical genetics
ZG	zoological genetics
B	bacteriology, biochemistry
EP	experimental physics
EPC	experimental physical chemistry
TP	theoretical physics
TPC	theoretical physical chemistry
EPs	experimental psychology
CPS	clinical, social or child psychology

contributions, this difference is not easy to estimate, so far as I can assess it in their work, it seems to consist largely in manner of approach to problems The life histories furnish some indication that there were also differences in interests (as shown in spontaneous activity) in high school and early college days Among biologists and physicists, very strong interest in the classics—music, art, and

TABLE II

ASSOCIATION BETWEEN FIELD OF SCIENCE AND IMAGERY TYPES

	A. Visual	B Verbal	C Imageless	Totals
Biologists	10	4	3	17
Physicists	10	4	4	18
Psychologists and Anthropologists	2	11	6	19
	22	19	13	54
	X^2 11 65	P 05– 02		

A includes subjects using visual imagery or this with visual symbolization or imageless thoughts or both
B includes subjects using verbal imagery, or this with verbal symbolization or imageless thought or both.
C includes only subjects who describe no visual, verbal, or other imagery modality and are classed as using imageless thought only

literature—were mentioned only by A2, P1, P4, P5, ZG3, EP1, EP8, TP1 and TP9 It will be noted that four of these biologists are among the six biologists who use verbal imagery and that three of the physicists are among the four physicists who report only imageless thinking Among the psychologists, interest in literature, or in writing as a career, is very common, and their concentration in the verbal group has already been noted Ps5 and An6, who use visual imagery, had no real interest in literature or art, so far as I could determine, at any age

IMAGERY AND OCCUPATIONS OF FATHERS

In view of the general dearth of information on the circumstances under which different subjects come to rely upon one type of imagery rather than another, I looked into the family backgrounds of these men, with the results noted in Table III. If more than one occupation was followed by the father of any subject, that which he followed while the subject was growing up is the one recorded Occupation of the father is fairly adequate as a single clue to general socioeconomic background, but other aspects are of greater interest here

It does not seem explicable on grounds of mere coincidence that five of the six sons of lawyers and all of the three sons of clergymen are in the group with strong verbal imagery So are two of the four sons of college teachers (their fathers taught music and educational administration, the fathers of the other two taught chemistry and a combination of economics, mathematics and English) As a check the professional fathers were separated into those whose

TABLE III

IMAGERY AND OCCUPATIONS OF FATHERS OF SUBJECTS

Occupation of Father	Imagery Category of Sons			Total
	A Visual	B Verbal	C Imageless	
Professional	13	12	5	30
Lawyer	0	5	1	6
Engineer (civil, construction)	3	1	2	6
College teacher	1	2	1	4
Physician	2	1	0	3
Clergyman	0	3	0	3
Elementary or high school teacher or superintendent	2	0	1	3
Newspaper editor	2	0	0	2
Astronomer	1	0	0	1
Pharmacist	1	0	0	1
Optometrist	1	0	0	1
Business	6	6	4	16
Executive or own business	3	3	3	9
Real estate	1	2	0	3
Purchasing agent, superintendent	1	1	0	2
Clerk, salesman	1	0	1	2
Skilled labor	0	0	1	1
Farmer	3	1	2	6

work would normally require a greater or lesser facility in verbal manipulation, e g , lawyers, clergymen, teachers, and editors, as distinguished from physicians, engineers, etc. The resulting tabulation is shown in Table IV Chi-square for a 2 × 2 table using only the first two columns is 5 22, and P is 02 − 05 [4] On psychological grounds there is no difficulty in rejecting the null hypothesis But there is no evidence here as to whether the association is due

TABLE IV

SUMMARY, IMAGERY AND NATURE OF WORK OF PROFESSIONAL FATHERS

Nature of Profession of Father	Imagery of Son		Imageless	Totals
	Visual	Verbal		
Verbal	5	10	3	18
Nonverbal	8	2	2	12
	13	12	5	30

[4] If Yates correction is used (this being a borderline case) P falls between 05 and 10

to some genetic character or to association with a father who, it is fair to assume, was facile in verbal expression

Imagery and Test Data

It seemed worthwhile to examine some of the test data for possible associations with imagery classification For this purpose only the subjects who could be classified in Table II were used This number is further reduced by some deficiencies in the test data, but 51 subjects were available for most of the comparisons Table V gives the figures for such test data as seemed to be relevant I have considered only the visual (A) and verbal (B) groups in this comparison, since both groups contain subjects who also use imageless thinking

Several of the subjects remarked that they now make less use of specific imagery than they used to, but differences are not noticeable within this age range Galton suggested the possibility of changes with age

The tests of verbal, spatial, and mathematical functions (supplied by the Educational Testing Service) are of conventional types, and it may be seen that there are some differences in means The most marked is in that for the verbal test (antonyms) those whose statement of typical thinking denotes high reliance on verbal imagery do very well on this test, although P for the difference is 05 to 10 The spatial test (a test of recognition of representations of 3-dimensional figures rotated through space) seems not to differentiate between the groups The verbal-spatial correlation for the total group was + 32 From descriptions of how the test was done, it is evident that more than one approach is possible Mare (7) found that "spatial imaginative faculty," which I take to be related to that involved in the spatial test used, can be compensated considerably in some tests by intellectual reflection

The mathematical test (involving reasoning as well as calculation) also shows a difference between means for the groups, but in the reverse direction The numbers in this test are very small, since it was not difficult enough for the physicists Correlation between verbal and mathematical tests for the total group is + 14

Brower (2) found no relation between the intensity value of images of various modalities, experienced in response to verbal

stimulation, and the Otis Since the Otis is an omnibus test, this does not contradict the results reported here

TABLE V

COMPARISON OF VISUAL AND VERBAL GROUPS ON VARIOUS TEST DATA

		A	B	For Difference Between Means*	
				t	P
N		22	19		
Age	range	37-58	31-58		
	mean	47 4±1 45**	47 4±1 65		
Rorschach data					
R	range	10-81	11-186	2 980	< 01
	mean	27 6±3 88	61 7±11 09		
T/R	range	22-97	17-65	2 635	02 >P > 01
	mean	46 4±4 79	32 1±2 84		
ITS	range	2-16	5-15		
	mean	9 8± 79	10 5± 74		
M	range	0-9	1-18	2 671	02 >P > 01
	mean	3 1± 48	6 1±1 05		
W%	range	11-100	6-67	3 003	< 01
	mean	4 60±4.56	28 7±3 75		
Rorschach Dd%					
	range	0-29	0-37	3 187	< 01
	mean	9 1±1 79	18 0±2 23		
F%	range	10-63	16-59		
	mean	38 5±3 09	39 6±2 73.		
F'+%	range	64-100	67-100		
	mean	88 5±2 34	87.1±2 31		
TAT					
length of stories,	range	5-47	7-49	1 510	<.10
	mean	14.2±1.77	18 6±2 41		
VSM test					
V raw score,	range	8-72	43-75	1 763	.05—.10
	mean	52.5±3 93	62 2±4 05		
S	range	3-22	3-19		
	mean	11.2±1 12	11.4±1.38		
M	range	8-27	2-27	1.570	< 10
	mean	16 6±1.89	12 5±1 97		

*t and P are entered only for mean differences with P< 10
**standard error of the mean.

Data on the Rorschach were also examined with respect to this imagery classification Difference between the groups in number of responses (R) is very great, as shown in Table IV, with the verbalists giving many more responses If this merely indicates considerably greater verbal fluency in this group, one would expect length of TAT stories to show a difference also, but such is not the case I suggest the difference may be due rather to an inhibiting effect—perhaps subjects accustomed to relying upon visualizations are more constrained when an unstructured stimulus is actually present, the fact that the visualists use significantly fewer Dd's is pertinent here On the other hand, if this were the case, one would expect some differences in F% and F'+% (F designates a response determined by form alone, and F'+% the percentage of these responses which are good form) W% (or percentage of responses using the whole blot) is markedly higher in the visual group This is probably largely if not entirely a function of the increased R which would not affect F% in the same way This large difference in R makes evaluation of other differences almost impossible, except the T/R or time per response This is significantly longer in the case of the visual group A recent paper by Raju (9), utilizing a word-association technique for visual and auditory stimuli, suggests that fast reactions are seldom accompanied by sense impressions

The items on the Inspection Check List did not appear to differentiate between these groups, and are not reported here The total number of checks, however, does show a small difference in means which is not significant

It would seem, then, that there are differences in mode of thinking which may be somehow related to socioeconomic background, and which are related to vocation and to certain aspects of test performances

My data offer no information on why subjects have come to rely on some modes of thinking rather than others Whether there is a hereditary factor, as Galton suggested, or whether it is largely training or experience, and if so how early and by what means the mode is set and how changeable it is are unsolved but fascinating problems As to manner or cause of development, leads might be obtained from cultural anthropology as well as from case histories,

as has been done here The association with test performance, suggested here, could be easily pursued The vocational aspect also warrants further investigation, with particular regard to its implications for training The relation of imagery to perceptual characteristics of the sort currently being investigated by Witkin and his associates (13) is another important line of research. The first need, of course, is for some more adequate techniques upon which to base categorization of subjects Development of such techniques would open all of these problems to direct investigation and would, finally, shed much light on the whole problem of thinking, particularly of "creative thinking"

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