SPECIAL REPORT

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THE INTELLIGENCE OF THE ADULT

(Its problems and methods)

III

The Intelligence of the Scientist

(Practical Part)

C

The Intelligence of Electrical Engineers and Mathematicians

NATIONAL INSTITUTE FOR PERSONNEL RESEARCH
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

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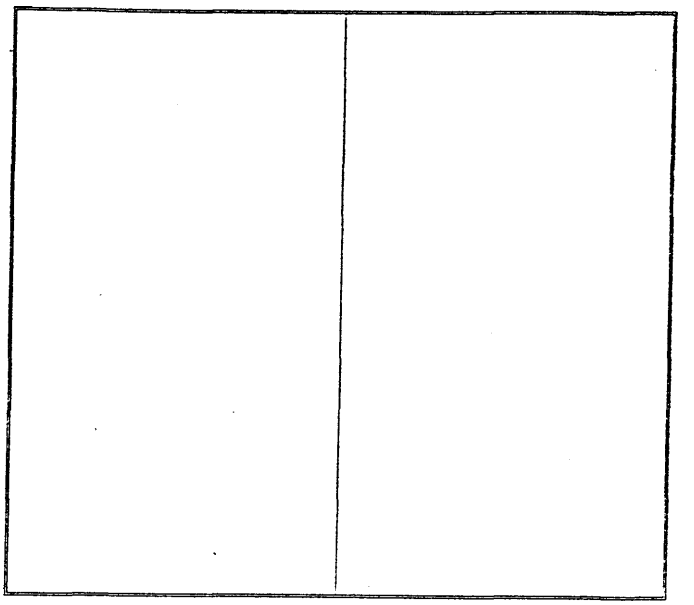

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The Intelligence of Electrical Engineers and Mathematicians.

C. O. E. Süssenguth.

September, 1970.

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CONTENTS

1. Introduction.

Since 1966 the emphasis of the C.S.I.R. Personnel Selection and Vocational Guidance Division's research has been on the more intensive study of the criteria used for the selection of C.S.I.R. personnel. Attention is being given to the problem of differentiating more effectively between the various occupational groups within the C.S.I.R., particularly the scientific careers, and the demands made in terms of level of functioning. In this respect the nature of the intelligence required is being studied more intensively.

On the basis of his experience in personnel selection, P.R. Skawran (38), recognized and defined some of the shortcomings in the selection of C.S.I.R. research staff. Considering these shortcomings as a deficiency in test-theory, he developed a structural model of the intelligence of the scientist on the basis of phenomenological assumptions. From this model, new test-concepts were deduced which imply two basic demands:

1. When selecting research staff, the testing of intelligence should be more specifically related to the intellectual demands of the jobs.
2. Selection should be specifically related to the academic professions and age groups tested.

Using theoretical assumptions and considering the more pragmatic demands, P.R. Skawran provided a framework for the empirical investigation of new test concepts.

It was decided that the first step of such an investigation should be the establishment of factual information concerning the intellectual demands of different academic jobs on different levels. As a method, the N.I.P.R. job analytic and evaluation approach was chosen. Using this method, posts of incumbents of different academic professions represented in the various institutes of the C.S.I.R. were to be analysed.

The first group of academic professions chosen for the study

was that of qualified librarians. Their jobs were analysed, and a report by P.R. Skawran (39), was published on the results of this analysis. The basic findings regarding the intelligence structure of the librarian can be summarized as follows:

The ability to comprehend concepts clearly, where abstracting and analysing processes are involved, was considered as a central intellectual characteristic of the librarian. This characteristic was described as being systematic and analytic in nature. To a lesser extent, "concretifying" intelligence could be identified. It was also recognized that the activities of a librarian involve practical, flexible, administratively-orientated and social intelligence. Higher levels of library work involve applied practical intelligence.

On completion of the study on librarians, it was decided to analyse and evaluate posts of research officers in the National Institute for Mathematical Sciences in the same way as was done with the librarian posts.

Using P.R. Skawran's concepts as a guide-line, the basic aims of this study can be formulated as follows:

(i) To investigate the structure of intelligence of mathematicians and electrical engineers.

(ii) To investigate the relationship between decision-making and the structure of intelligence.

(iii) To investigate whether the intelligence of the adult differs from the intelligence of the younger person.

2. Study Approach.

In order to obtain the necessary information on the intelligence of mathematicians and electrical engineers, the N.I.P.R. job description method was used. This job description method has been described in the preceding report on "The Intelligence of the Librarian" by P.R. Skawran. Briefly it comprises a semi-structured interview with a job incumbent; the preparation of a written job description on what the incumbent does and the essence of how he does it; followed by a systematic analysis of his work in terms of a number of factors (the processes involved in his decision making being the key factor); and finally a comparison of the different jobs according to their factor content by means of a job evaluation process.

This method of job description was applied in the same way during this investigation. Although it was realized during the study that some methodological alterations appeared to be advisable, no changes have actually been carried out. This was done to maintain the principle of "isolating variance" (Arnold), i.e., to try to keep constant all but one variable in a psychological experiment.

3. Scope.

The study was limited to the description and analysis of posts of research workers employed by the National Research Institute for Mathematical Sciences and included the following departments and divisions:

(i) Electrical Engineering Department:

Divisions:

(a) Automation.
(b) Solid State Electronics.
(c) Applied Electronics.
(d) Electronic Instrumentation.
(e) Power Electrical Engineering.

(ii) Mathematical Sciences Department:

Divisions:

(a) Mathematical Analysis.
(b) Statistics.
(c) Numerical Analysis.

Job descriptions have been obtained from:

7 Assistant Research Officers.
8 Research Officers.
5 Senior Research Officers.
3 Chief Research Officers.
3 Senior Chief Research Officers.
1 Director.

TOTAL: 27 Job descriptions.

4. Progress.

This project was started in 1968. Due to unforeseen circumstances, e.g. unavailability of staff, training of new staff members, etc., the progress of the investigation was relatively slow. Further delay was caused by the fact that no clearly defined method could be found to transform information obtained from job descriptions into valid statements on the forms of intelligence necessary for the performance of jobs. Several methods were applied, ranging from descriptions of "self-perceived mental processes" to purely subjective evaluations of intellectual abilities involved in the performance of jobs. Finally a method was developed which appeared to satisfy the demands for objectivity, viz. a suitably modified job evaluation approach.

The co-operation of all research workers interviewed was very good, bearing in mind the long and strenuous interview session.

5. Methodological Aspects of the Study.

5.1 Interpretation and Classification of Factor Contents.

Generally speaking, the information obtained concerning the factors "Decisions", "Controls and Checks" and "Contact with People" presented no interpretational difficulties and was valuable. A comparison of the 27 job descriptions, however, revealed some interpretational problems regarding the content of a number of factor descriptions, particularly the differentiation and classification of intellectual abilities and required aptitudes of mathematicians and engineers. In this respect the information obtained under the factor "Education and Experience" could not be interpreted meaningfully. Asking the question: "What was of real value in your university education with regard to your present job?", merely generated answers containing very specific details of a technical and mathematical nature (e.g. "Matrix Algebra", "Mathematical Analysis", "Electronic Circuit Design", etc.), with the result that no useful classification or interpretation could be made. Also the question: "Why are these subjects of real value to your present job?" merely elicited very specific technological interpretations (e.g.: "Because Matrix-Algebra is used in solving compound equations so that I can perform mathematical proofs"). The same difficulties occured when asking the incumbents to indicate their "knowledge gained in previous positions for which no provision has been made in formal academic training".

The factor "Required Education and Experience" also presented an interpretational problem, e.g. when having to compare "Ph.D. in Mathematics and 4 years experience in working in a computer centre" with "M.Sc. degree in Mathematics and 6 years experience in working in a research organization".

Only the factor "Required Experience" with the question "What is the required experience necessary for the execution of your job?" provided meaningful information for a logical classification of jobs.

The factor, "Numerical computations", usually used in the N.I.P.R. job analysis approach, was omitted in this investigation because mathematical and arithmetical manipulations and computations form an essential part of all engineering and mathematical jobs. The manner in which mathematical and numerical computations are used in the different jobs, thus forms part of the job description.

5.2 Job Evaluation.

Based on the information obtained from the job descriptions and utilizing the usual N.I.P.R. job evaluation procedures, factor rating scales with defined scale-points were drawn up for each factor. This was done for the factors "Decisions", "Controls and Checks", "Contact with People", "Language Usage" and "Experience" (see Annexure). 5 Raters subsequently rated each factor of each job description independently, using the developed factor rating scales. (The inter-rater agreement was $r = .96$). Each assessment of a factor was discussed in detail to arrive at a final "score". This procedure assisted in rank-ordering all jobs on each factor in terms of the complexity level of the job demands for the factors.

-On completion of this exercise the "scores" obtained were converted by means of a simple interpolation method. This was necessary since the scales used were not of equal length and prevented an effective comparison and combination of all factor "scores". The interpolated and converted "scores" for all factors were then added to obtain the final overall ranking of a job. Having obtained an effective ordering of the

27 jobs, this rank-order was closely studied in order to determine a spontaneous grouping of these jobs into grades. This classification of jobs into job complexity grades was done by considering the essential similarities of jobs, i.e., in terms of their basic characteristics and their complexity level of functioning. In this process the characteristics of an incumbent's decision processes provided the most effective answer.

6. Job Evaluation Results.

6.1 Grade Classification.

The job evaluation resulted in a classification of the twenty-seven jobs into six grades.

GRADE I.

Posts which were classified into this grade are the following:

A.R.O. Electrical Power Engineering.
A.R.O. Solid States Electronics.
A.R.O. Statistics.
A.R.O. Electrical Engineering.

Typical "beginner jobs" where incumbents are learning to apply basic principles and techniques (e.g. behaviour of circuits under different conditions, etc.). Incumbent applies logical "step by step" procedures as well as trial and error methods. Applies mathematical formulae, rules and regulations, as well as knowledge of handling apparatus (e.g. oscilloscope, etc.), and components (e.g. of circuits). Describes facts and results of own work by giving verbal and written reports. This requires knowledge of specific technical

terminology pertaining primarily to his own field of work.

Limited number of clearly defined alternatives (e.g. to design a circuit with an open loop amplifier or a closed loop amplifier) where the most suitable one is selected. Decisions are characterized by relating demands of tasks with their well defined specifications for the experiments (e.g. specifications of electronic components, computer prescriptions, etc.), to own factual knowledge (e.g. university knowledge on basic electronic principles, etc.) and to his limited experience (e.g. experience on quality of components, etc.). Acts on clear cut cues regarding the correctness of a decision (e.g. failing units of electronic circuits lead to necessary alterations of the circuit), the availability of laws and principles and his limited experience on previous tasks.

Detailed and regular control. Specific instruction concerning a task from superior. Incumbent checks on his own progress and quality of work, e.g. by noticing the malfunctioning of parts and immediately applying the necessary correction himself.

On completion submits results to superior. Consequence of error practically nil.

GRADE II.

Posts which were classified into this grade are the following:

A.R.O.	Applied Electronics.
R.O.	Numerical Analysis.
R.O.	Electrical Power Engineering.
A.R.O.	Statistics.
A.R.O.	Electronic Instrumentation.
R.O.	Solid States Electronics.

Primarily involved in performing a number of tasks

(e.g. for customers), where he applies techniques and methods (e.g. Variance Analysis) selfreliantly and is familiar with manipulating apparatus and the use of instruments, etc., with a view to the facilitation and speeding up of work. Tasks are analysed in a critical manner, amongst others adapting theoretical knowledge to practical problems. Anticipates the necessary steps for the implementation of tasks, as well as the limitations and the technical implications of different procedures. Interprets technical information relevant to his own work and writes reports (pertaining to own work) on general lines of action. Transforms technical language into "popular" language in order to communicate with lay-men.

Alternatives less readily available and defined, some of them tentative for short-term trial and error solutions to a given problem (e.g. how to overcome d.c. shift). Decisions are characterized by collecting and comparing information (e.g. descriptions of different apparatus, etc.). Guided by logical deductions and analyses which are based on knowledge and experience in a specific field (e.g. own experimental set-up and calculations are used in order to find cues for decision). Is frequently responsible for small projects or tasks.

More general instructions and irregular control by superior with regard to his research techniques and procedures. Recognizes own mistakes and the need for correction. Quality of work is checked by the quality of completed tasks and the acceptance by customers. Consequence of error usually means repeating the task/s and thus some loss of time.

GRADE III.

Posts which were classified into this grade are the following:

R.O.	Solid States Electronics.
R.O.	Statistics.
S.R.O.	Applied Electronics.
R.O.	Numerical Analysis.
R.O.	Electrical Engineering.
S.R.O.	Mathematical Analysis.
S.R.O.	Electrical Power Engineering.
R.O.	Automation.
S.R.O.	Numerical Analysis.

Involved in research and investigations on scientific and technical problems in a given field. Work may entail handling of administrative and organizational matters (e.g. keeping time-sheets for sub-ordinates, controlling their work progress, etc.), resulting in co-ordination and organization in clearly defined and limited fields (e.g. organizing a production line, etc.). Problem consciousness is used in order to recognize, circumscribe, anticipate and define shortcomings and difficulties in technological or mathematical research. Integration of abstract and concrete principles, where abstract manipulations are performed. Provides original solutions and ideas (e.g. new method to produce quasi-stereo effects) by relating and combining similar methods or fields (e.g. stereo and echo effects) and disengaging himself from a pre-fixed pattern of thought. Good understanding of technical information (also when condensed) and recognizing the essential aspects and underlying principles of written and spoken matters. Clear and concise expression in writing publications, addressing public meetings, etc., and acting in a convincing manner by logical presentation of technical facts.

Decisions are characterized by the accumulation and evaluation of information, reducing it to its fundamental characteristics and the application of newly gained insight to unfamiliar problems in a given field. Alternatives are evaluated in terms of the wider applicability of their underlying principles.

They are also developed in the form of original new solutions (e.g. completely new circuit design, etc.). Guided by cues obtained from analysis of alternative solutions, systems, approaches and the recognition of their interrelations and implications, particularly regarding the time and cost of a project. Responsibility for own project and/or responsibility for projects of subordinates, requiring consideration of consequence of error.

Controls primarily in form of approval for own projects by discussing them with superior and specialists. Quality of work is checked mainly indirectly by budget and time expenditure, final reports, appreciation of customers and the acceptance of research results for publication. Mistakes may have negative effects on image of Division or Institute.

GRADE IV.

Posts which were classified into this grade are the following:

C.R.O. Applied Electronics.
S.R.O. Statistics.
S.C.R.O. Electrical Engineering.
S.C.R.O. Solid State Electronics.

Primarily concerned with sponsoring and initiating research projects as a "professional authority" within a field covered by the Division (e.g. "Electronic Instrumentation", "Statistics", etc.). Greater involvement in organizational and administrative tasks of the division where co-ordination and integration of general aims of research (e.g. developing of integrated circuits, etc.) with the strategy of the institute, takes place. Ready conceptualization of essential aspects regarding technical and general information. Verbal fluency and interpersonal skills becoming more prominent, particularly

with regard to the skills involved in presenting technical arguments.

Variety of alternatives, the consequences of which are simulated. Alternate solutions have to be devised and evaluated on the basis of background knowledge. Decisions are characterized by anticipation of especially those problems pertaining to the division and institute.

Controlled by formal approval for a number of projects initiated by incumbent. Responsibility for the direction, co-ordination and completion of projects within the division lies with incumbent. Quality of work is checked by the general success of research work of division and/or scientific approval of publications. Mistakes influence the efficiency and progress of work of the division and may have negative effects on the institute and the C.S.I.R. (e.g. poor image of the institute).

GRADE V.

Posts which were classified into this grade are the following:

C.R.O. Electronic Instrumentation.
C.R.O. Electrical Power Engineering.
S.C.R.O. Numerical Analysis.

As Head of Division, involved in activities outside the Division, the Institute or the C.S.I.R., where he renders services, not only in an advisory capacity but participates actively in outlining and initiating new developments pertaining to a specific field of research (e.g. developing new forms of computer services, educational systems, etc.). Considers and anticipates trends and developments from different fields (e.g. economics, industry, etc.), including considerations regarding hypothetical future situations and how this might affect the Division's field of research (e.g. industrial demands

with regard to computer industry, etc.).

Comprehensively applies his technical and social experience in negotiations in order to convince and persuade senior research workers, colleagues and representatives of fields other than his own (e.g. industry, economics, etc.).

Variety of alternatives pertai ning to his own research field have to be evaluated in relation to other fields. Decisions are characterized by anticipation and long-term planning of research efforts and their practical implementation, incorporating such management aspects as the utilization of personnel, economics and budgeting, deciding on priorities, co-ordination of research, etc.. In this respect he also operates outside the context of his Division, involving e.g. the Institute.

Controlled by formal approval for new developments he initiated and recommended. They are evaluated by specialists, experts and committees. Quality of work is controlled in the form of criticism on the merits of his reports, publications and contributions. Mistakes may have negative effects on the C.S.I.R. as a whole (e.g. creating the image of incompetence of scientists employed at the C.S.I.R., and consequently the loss of contacts and future sponsors, etc.).

GRADE VI.

Posts which were classified into this grade are the following:

Director of Institute.

Activities in- and outside the Institute and the C.S.I.R. require the perception of international, national and industrial research problems and needs and subsequently the stimulation, initiation and conceptualizing of new approaches, developments and innovations with a view to the solving of such problems and providing a national research service in the fields covered

by the Institute. Attainment of his long-term objectives demand insight into and anticipation of complex hypothetical situations in a variety of fields (e.g. economics, science, industry, etc.), and the need to view matters in perspective and to integrate different interacting factors and problems against a comprehensive information background. Ensures implementation of his plans by organizing, co-ordinating and reconciling different and sometimes conflicting aspects, as they affect the Institute both from within the C.S.I.R. and from without. In this process he applies management principles extensively, e.g. with regard to personnel material and money, the administration and control of the Institute's activities, the broad C.S.I.R. policy implications, etc..

Reacts to subtle points and "undercurrents" (e.g. by "reading between the lines", listening to discussions, etc.), in analysing information. While negotiating, he determines the strategy of others and adapts his own approach accordingly. This frequently involves an indirect approach, and long-term and subtle manipulation of people to achieve the ultimate purpose of the Institute, thus creating a positive image of the Institute, etc..

Variety of different and interrelated alternatives, few of them predetermined, little or no precedence, consisting primarily of complex and interrelated systems and basic approaches. Decisions are characterized by the readiness to take responsibility for far-reaching consequences and for the correctness of hypothetical future situations, serving as a guide for his decisions.

Although formal control is exercised by scientific bodies and advisory committees, initiative for new developments eminate primarily from the incumbent himself. Quality of work is subject to scientific and industrial approval. Mistakes may induce erroneous developments in scientific and industrial fields.

6.2 Categories of Intellectual Characteristics.

The utilization of the job description and job evaluation method was intended to provide factual and basic information and to ensure a systematic and objective approach. Being independent from the theoretical concepts on the intelligence structure of scientists and aimed primarily at describing the activities of research workers, it was inevitable that the information given, e.g. as defined in the various job evaluation grades, still tends to be task-anchored and does not lend itself to a direct and specific identification of intellectual characteristics. Nevertheless, the procedures used did constitute a first phase in attempting to reduce the highly technical content of research activities into more manageable, and fundamental terms.

The results so far, therefore, do still contain a relatively large proportion of functionally descriptive terms which lend themselves to distorted and subjective interpretation, e.g. in terms of "social perception" processes. Before attempting to interpret the results and to relate them to intelligence structure concepts, it was necessary to subject the job evaluation grade definition contents to a form of content analysis with the following objectives:

(1) To identify intellectual qualities.

(2) To define the identified intellectual qualities.

(3) To provide a typical example of an activity requiring the specific intellectual quality.

(4) To group the identified qualities in a progressively more demanding order, i.e. in terms of differentiating categories of intellectual characteristics.

In this manner the job evaluation content was reduced to the following three categories of intellectual characteristics:

CATEGORY I.

1. Problem Analysis.

   Definition: Ability to resolve critically, concrete and abstract information into its constituent elements.

   Illustration: Analysing the results and methods used to compile information on the influence of fungicides on wood.

2. Concept Selection.

   Definition: Ability to understand theoretical concepts and to select an appropriate one for application.

   Illustration: Selecting the right mathematical formulae for the statistical analysis of a given problem.

3. Logic Manipulations.

   Definition: Ability to maintain aim-directed, "step by step" procedures in handling concrete and abstract material according to fixed laws and rules.

   Illustration: Building up electronic circuits according to laws of physics, and solving mathematical equations according to computation rules.

4. Logic Prescience:

   Definition: Ability to foresee actions and reactions in an abstract or concrete scheme.

   Illustration: Foreseeing various reactions of a computer, when a particular action is taken.

5. Fault sensitivity.

   Definition: Ability to respond readily, with appropriate actions, to conditions deviating from fixed rules and regulations.

   Illustration: Immediately recognizing when behaviour of a circuit deviates from expected behaviour.

6. Verbalize Technical Procedures.

   Definition: Ability to explain and describe concrete and abstract procedures in an intelligible way.

   Illustration: Reporting in a written and spoken manner on how a circuit was built up.

This category includes the job evaluation Grades I and II.

CATEGORY II.

1. Problem Sensitivity.

   Definition: Ability to recognize, circumscribe and define problems involved in a project.

   Illustration: Recognizing that reducing of values to two points is basically an "initial value problem".

2. Concept Analysis.

   Definition: Ability to reduce concepts to their fundamental characteristics, recognizing their interrelations and implications.

   Illustration: To reduce the mathematical definition of red blood cells to an analytic calculation of properties of a model of a cell.

3. Creative (productive) Imagination.

Definition: Ability to disengage oneself from a pre-fixed pattern of thoughts and combine different methods, thus originating new solutions.

Illustration: Disengaging from the obvious solution of improving the mechanical functions of a graph reader by relating the construction problem to potential lines in earth measurement, obtaining, therefore, an original and new solution of constructing a graph reader which works with equipotential lines.

4. Logic Anticipation.

Definition: Ability to imagine and conceive a variety of arguments, actions and reactions, so that they are in accordance with a particular scheme.

Illustration: Anticipating and exhausting all possibilities of calculations for a system of 150 modules of a computer.

5. Verbal Precision.

Definition: Ability to express oneself verbally and in written manner to present information in a structured and concise form.

Illustration: Distinguishing between the important (relevant) and the unimportant (irrelevant) and structuring (grouping) the information content under suitable headings.

This category includes the job evaluation Grade III.

CATEGORY III.

1. Problem Integration.

   Definition: Ability to combine a variety of different problems in such a way that they can be solved by the co-ordination of various activities.

   Illustration: Organizing the tasks and projects of a division and/or institute in an effective and efficient manner.

2. Conjectural Anticipation.

   Definition: Ability to conceive and simulate hypothetical and complex future situations and to anticipate variables which could have an effect on these.

   Illustration: To plan a computer service for South Africa.

3. Fluent Verbalization.

   Definition: Ability to communicate ideas and thoughts immediately, formulated in a concise and clear manner.

   Illustration: To contribute quickly, constructively and concisely during discussions.

4. Judgemental Confidence.

   Definition: Ability to make decisions, the correctness of which cannot be determined readily. Such decisions are based partially on the personal conviction of acting in the right manner.

Illustration: Deciding on specific education system for technicians.

4. Application of Social Techniques.

Definition: Ability go guide, lead and motivate sub-ordinates in an indirect manner and to act convincingly towards peers and superiors.

Illustration: Giving a subordinate literature studies on a subject not closely related to his actual field of work, so that he takes an interest in a new subject which is liable to give a good application in future.

This category includes the job evaluation Grades IV, V, VI.

7. Discussion.

The initial discussion of the results of the study involves, primarily, comparisons of the categories of intellectual characteristics with P.R. Skawran's theoretical assumptions. The results are then compared with other intelligence concepts relevant to the findings of the investigation.

7.1. Comparison of the Results with Theoretical Assumptions.

(i) With regard to the structure of intelligence Skawran distinguished between "analytical and synthetical intelligence, practical-technical and theoretical, abstract and concrete intelligence" (38, P. 67). -Some of the intellectual characteristics described in the categories can be interpreted as analytic "intellectual qualities" (e.g. "Problem analysis", "Concept selection") and others as "synthesizing" mental activities (e.g. "Productive

imagination", "Problem integration") or as "Practical Intelligence".

Due to the limitations of this study, a clear identification of the relationships existing between the theoretical assumptions of practical-technical and theoretical, abstract and concrete intelligence, and the intellectual demands necessary for the performance of jobs of electrical engineers and mathematicians was not possible. If the job descriptions were interpreted in terms of the "forms of intelligence", it would be apparent that most of the latter can be found on the different job levels. However, these qualities, e.g. abstract or concrete intelligence seem to be so global, that they occur in practically every action or form of behaviour that can be classified as "intelligent". For instance the use of language can also be considered as a process of abstraction where one is involved in "separating mentally or in words a quality or aspect of a thing from its concomitants." (English and English (11, P. 3)). However, it seems logical to presume that the processes of abstraction involved in language usage are simpler or less complex than those which are necessary for the performance of intricate mathematical analysis. However, statements pertaining to a quantitative differentiation such as "lower and higher" or "more and less" can only be proved by purely quantitative methods. In this respect a procedure which utilizes a basically qualitative approach as was done in this study, is inadequate in providing valid results of a quantitative nature.

(ii) P.R. Skawran distinguishes between three different types of intelligence of the scientist, necessary for the

performance of jobs on different levels (38, P. 104, Fig. 17).

Similarly, in this study, 3 categories of intellectual qualities necessary for the performance of jobs of different complexity could be identified. Comparing these three categories with P.R. Skawran's 3 types of intelligence, it is apparent that there are considerable differences with regard to the grouping of posts. In Skawran's classification, Assistant Research Officers, Research Officers and Senior Research Officers were grouped together under one type of intelligence necessary for the performance of the jobs on these levels. The first category in this study, however, embraces posts primarily on the Assistant Research Officer-level and some on the Research Officer-level, indicating intellectual qualities which are necessary for the performance of jobs on the "beginner-level".

P.R. Skawran's next level of intelligence includes Chief Research Officers and Senior Chief Research Officers, whereas our second category includes posts on the Research Officer and Senior Research Officer-level, indicating the intellectual qualities necessary for the performance of a typical research worker or innovator's job.

P.R. Skawran's highest grade includes the posts on the Director, Vice-President and President-level, whereas this study's third category includes posts on the Senior Research Officer, Chief Research Officer, Senior Chief Research Officer and Director of Institute-level. Because of the limitations of this study, it cannot be determined in how far the posts on the Vice-President or President-level would fall into this category, or whether other intellectual qualities would have been identified.

(iii) It is essential that a scientist should have the ability to make intelligent decisions (38, P. 12 & P. 134). In order to examine the question of how decisions are related to the work of mathematicians and engineers, one has to refer back to the job evaluation grades and also consider the categories of intellectual characteristics. From the grades, it can be deduced that decisions imply pure cognitive qualities and as "concept selection", "logic prescience and anticipation", "productive imagination" and "problem integration". In fact we find that nearly all intellectual qualities, as described in the categories, can be deduced from the kind of decisions which are made on the different job levels. On the other hand, one finds that in the higher grades (indicating higher levels of job complexity), the act of deciding requires specific qualities which can be attributed to volitional and/or emotional factors. This finding is also represented in the interpretation of the job evaluation grades where it was found that "judgemental confidence" (the ability to make decisions, the correctness of which cannot be clearly determined, so that they are based on personal conviction to act in the right manner) is a central characteristic of the posts covered by the third category of intellectual characteristics.

These results are in close conformity with P.R. Skawran's theoretical assumption that "the ability to decide intelligently" is based on "emotional and volitional factors, which have a close structural relation to the intelligence" ... and thus support his demand to use tests for selection purposes "which do not aim at the intelligent solution of questions tied to tasks, but ... which prove the ability to make intelligent decisions". (38, P. 134).

(iv) "The intelligence of the human being undergoes a vital structural change during his course of ageing as revealed in the concepts skill, prudence, and wisdom" (38, P. 9).

Since the three categories of intellectual qualities derived from this study cannot be interpreted in terms of the abovementioned concepts ("skill", "prudence" and "wisdom"), the results of the study cannot be used to support the above statement. -Considering the average ages of incumbents covered by the three classes, distinct age differences exist. (Average age of incumbents grouped into Category I = 24.5 years; Category II = 29.3 years; Category III = 44.2 years). However, one cannot deduce from these findings that higher intellectual qualities are developed on the different age levels as a function of the job and environment. According to Ertel (14), such a deduction could be considered as a rather "uneconomic organic principle" which contradicts one of the basic laws of psychology, viz. "not to refer to higher psychic functions if lower ones are sufficient to explain psychic phenomena". (Morgan's canon).

Consequently one can only state that the intellectual demands of jobs executed by older people are different from the intellectual demands of jobs executed by younger incumbents. At what stage these different intellectual abilities, which enable an incumbent to cope with the demands of a job, are developed cannot be established merely by using the job analysis method. Possibly the abilities necessary for the execution of an older person's job (e.g. jobs on a director's level, etc.), exist as "recessive" potentialities in younger age-groups, but cannot be identified because the execution of the jobs of this group do not require these abilities or intellectual qualities.

However, P.R. Skawran is correct in underlining the fact that the functions of the adult (within our society) cannot be taken over by younger persons, even though the "decline of intelligence of the adult" (as indicated by present intelligence tests) implies that they can (38, P. 3-9). As indicated in the job evaluation grades and the scale-definitions of this study, higher posts occupied by older persons can only be filled on the basis of wide experience and knowledge accumulated during the course of a career. This finding is also confirmed by Bäumler (4) who states that specifically in (higher) academic professions, scientific achievements depend to a large extent on the magnitude of knowledge and experience.

The above findings can be summarized briefly as follows:

(i) Due to the limitations of this study, the structure of intelligence as perceived by P.R. Skawran could not be clearly identified, although some similarities between his concepts and the results of the study have been found.

(ii) The classification of jobs according to P.R. Skawran's types of intelligence, differs from the classification of jobs revealed by this study.

(iii) The study strongly supports P.R. Skawran's theoretical assumption that the ability "to make intelligent decisions" is essential for the scientist. It has also been shown that the process of deciding is closely related to cognitive as well as emotional and volitional processes.

(iv) P.R. Skawran's intelligence concepts of "skill", "prudence" and "wisdom" could not be proved or disproved by our study.

7.2. The Results and their Relation to other Intelligence Concepts.

A comparison of the results of this study with other approaches towards intelligence seems to be useful in order to establish the extent to which our findings differentiate sufficiently between intellectual qualities and/or can be explained in terms of other intelligence concepts. A comparison of descriptions of intellectual abilities with those of other intelligence theories also seems to be useful in so far as it could possibly give indications for other more structurized investigations into the relationship between work performance and the testing of intellectual abilities.

7.2.1. Comparison with Guilford's application of an intelligence model to creative scientists.

Guilford's application of his structural intelligence model to creative scientists (1963) is very useful for this purpose because it appears to be closely related to this study. In order to educe how scientists (e.g. physical scientists, engineering psychologists, engineers, system engineers) evaluate the relative importance of some of the factors for successful work performance, Guilford asked them to rate the factors according to their importance in this respect. Twenty-eight factors were selected for the rating. In defining these factors, Guilford used a similar approach as was used in this study for the definition of job requirements and for the defining of the intellectual characteristics categories.

This facilitated the comparison between the description of Guilford's factors and the intellectual qualities deduced from this study. Guilford's factor definitions, as he relates them to the work success of scientists, read as follows:

TABLE I.

(Reproduced from Guilford : Intellectual Resources and their Values as seen by Scientists, (25, pp. 115-117).

The code designations, definitions, and examples of activities for the 28 factors rated by the scientists.

1. CMU - To have a good vocabulary or knowledge of meaning of words.
   Example: Reading a book without the aid of a dictionary.

2. CFC - To recognize the class to which a perceived object belongs.
   Example: Classifying a piece of ore.

3. CFR - To discover the relationships between perceived (sensed) objects.
   Example: To notice that one object is more pointed, smaller, heavier, or more complex than another.

4. CMR - To discover relationships between thoughts or ideas.
   Example: Seeing connections between socialism and a dictatorship.

5. CFS - To perceive the spatial pattern of objects.
   Example: Telling time from a watch seen in an inverted position.

6. CSS - To discover the complex relationship that exists in a pattern or system of symbols.
   Example: Deciphering a code.

7. CMS - To comprehend the nature of the basic relationships inherent in a problem preparatory to solving it.
   Example: Recognizing that sales may be increased by reducing the price of an object but that maintaining profits also requires reducing the unit production cost.

8. CFT - To visualize what a perceived (sensed) pattern would look like if rearranged.
   Example: Visualizing - without aid of drawings - what an instrument panel would look like if the dials were rearranged.

9. CMT - To see beyond the immediate and the obvious.
   Example: Recognizing that modifying the airplane itself may be a better solution to the problem of landing high-speed jets than lengthening the runways.

10. CFI - To explore visually several possible courses of action, preparatory to selecting the most effective.
    Example: Seeing ahead several moves in checkers or chess.

11. CMI - To anticipate the needs or the consequences of a given situation.
    Example: An administrator considering a proposed change in payroll form in terms of probable consequences.

12. MMU - To reproduce previously presented ideas.
    Example: To be able to recall what other workers have done in the solution of similar problems.

13. DMU - To produce many ideas where free expression is encouraged and where quality of ideas is not important.
    Example: Producing as many ideas as possible for the improvement of a product or new uses of it.

14. DMC - To produce a diversity of ideas in a relatively unrestricted situation.
    Example: Keeping out of ruts by jumping readily from one train of thought to another in thinking of new uses for some device or product.

15. DMR - To produce words from a restricted area of meaning.
    Example: To suggest several words as synonyms for "intelligent", such as "smart", "bright".

16. DFT - To abandon conventional problem-solving methods that have become unworkable and to think of original solutions.

Example: Putting the eye in the point of the needle to make the invention of a sewing machine possible.

17. DMT- To produce clever or uncommon responses to specific situations.
Example: Writing "It's time to retire" as a caption for a picture of a sleepy child standing near a worn-out tire.

18. DMI- To specify the details that will contribute to the development of a general idea.
Example: To suggest the specific steps that should be taken to set up a successful conference on creativity.

19. NSR- To suggest a symbol (such as a letter or number) that will satisfy a given relationship.
Example: Stating the smallest odd number that is also a perfect square.

20. NMR- To produce a response to fit a stated or implied relationship of ideas.
Example: Suggesting a substance that will adhere to another, will be tougher than another, will repel another, etc..

21. NMS- To arrange events or steps into an optimal sequence.
Example: Arranging in the proper sequence appropriate suggested steps relative to the ending of a labor dispute.

22. NFT- To give up one perceived organization of a visual pattern in order to see another.
Example: Seeing a wallpaper pattern first as one grouping of lines and then as another.

23. NST- To recognize that the elements of a structure can be reorganized in such a way that they will have new functions.
Example: Seeing that an algebraic expression, having been factored in one way, may be factored in another way if the terms are rearranged.

24. NMT- To shift the functions of an object, or part of an object, and to use it in a new way.
Example: Putting a cake of Dry Ice under a very heavy machine so that it sinks into place as the ice evaporates.

25. EFU- To recognize which member of a group of objects is identical to a given object in terms of appearance.
Example: Selecting from a handful of screws one needed to replace a defective one.

26. ESR- To manipulate symbols according to rules.
Example: To solve routine algebraic problems.

27. EMR- To use logical relationships in testing the correctness of a solution.
Example: Deciding that not all loans are profitable, even though some investments are profitable and all loans can be considered investments.

28. EMI- To recognize problems that may present themselves.
Example: Seeing that a gear is not functioning perfectly.

Comparing Guilford's factors with the intellectual qualities as defined in this study, suggests the following similarities:

TABLE II.

Guilford's Factors.	Interpreted in terms of:
4. Education of conceptual relations.	Concept analysis.
6. Education of symbolic patterns	Concept analysis.
7. General reasoning	Concept analysis.
9. Penetration	Logic anticipation.
10. Perceptual foresight	Logic prescience.
11. Conceptual foresight	Conjectural anticipation.
13. Ideational fluency	Creative (productive) imagination.
14. Spontaneous flexibility	Creative (productive) imagination.

16. Figural adaptive flexibility	Creative (productive) imagination.
17. Originality	Creative (productive) imagination.
21. Ordering	Problem integration.
26. Symbol manipulation	Logic manipulation.
27. Sensitivity of problems	Problem sensitivity.

Close conformity between Guilford's factor definitions and the intellectual analysis exists only in two cases, viz. between Factor 26, "Symbol Manipulations" and what was defined in the categories as "Logic Manipulations" and between Factor 27, "Sensitivity of Problems" and "Problem Sensitivity". "Logic Manipulations" is, however, not only related to the "Manipulation of Symbols" but is also related to the "handling of abstract and concrete material". Similarly, "Problem Sensitivity" circumscribes a larger problem area and is not only restricted to "problems that may present themselves", but includes "the ability to recognize, circumscribe and define problems involved in a project."

Further similarities exist with regard to the concept of "Anticipation". Guilford, in effect, distinguished three forms of anticipation, viz. Factor 9, "Penetration", Factor 10, "Perceptual Foresight" and Factor 11, "Conceptual Foresight". Three similar kinds of anticipation have also been identified in the categories: "Logic Prescience", "Logic Anticipation" and "Conjectural Anticipation". Nevertheless, there are some differences: "Perceptual Foresight" (Factor 10), is limited to "the visual exploration of possible courses

of action", while "Logic Prescience" includes foresight of "actions and reactions so that they are in accordance with a particular scheme".

Greater differences exist between Guilford's Factor 9, "Penetration" and "Logic Anticipation". While Guilford defines "Penetration" fairly generally "as seeing beyond the immediate and obvious", this study's definition, i.e. "the ability to imagine and conceive a variety of arguments, actions and reactions" is more specific. Guilford's "penetration" could possibly also be interpreted in terms of "Conjectural Anticipation". Factor 11, "Conceptual Foresight", is also related to this form of anticipation. The difference between them is that Guilford's factor delineates the "Anticipation of the needs or consequences of a given situation", while "Conjectural Anticipation" defines the simulation of a hypothetical situation.

Guilford's factors 4, 6 and 7 (Eduction of Conceptual Relations, Eduction of Symbolic Pattern and General Reasoning) could be interpreted only in terms of one of the intellectual qualities, viz. "Concept Analysis". This is due to the fact that Guilford differentiated more clearly between "discovering relationships between thoughts and ideas" (Factor 4), "discovering complex relationships that exist in a pattern of symbols" (Factor 6) and "comprehending the nature of basic relationships inherent in a problem" (Factor 7), while this study revealed more general definitions, viz. "reducing concepts to their fundamental characteristics, recognizing their interrelations and implications."

The concept of "Creative (Productive) Imagination" is also rather general in comparison to Guilford's factors. He distinguishes between four forms of

producing or originating ideas and solutions: "Ideational Fluency" (to produce many ideas), "Spontaneous flexibility" (to produce a diversity of ideas), "Figural Adaptive Flexibility" (to abandon conventional problem solving methods and think of original solutions) and "Originality" (to produce clever or original responses or solutions).

Although certain differences exist between Guilford's Factor definitions and this study's definitions of the intellectual characteristics of engineers and mathematicians, the factors and the intellectual qualities which have been related to each other seem to have a common denominator. E.g. the intellectual quality "Productive Imagination" has the concept of describing processes involved in originating new ideas and solutions in common with Guilford's Factors, 13, 14, 15, 16, 17. Thus, when examining the scientists' ratings of the importance of Guilford's factors to work success (which can be interpreted in terms of intellectual qualities), it appears that the findings from this study have a number of features in common.

The reproduced table (III) of Guilford shows the means of ratings of importance of Guilford's Factors to the creative scientists and rank orders of a Research Group and of a Non-research Group. The underlined factors are those which correspond to the intellectual qualities revealed by this study.

TABLE III.

(Reproduced from Guilford: Intellectual Resources and their Values as seen by Scientists, (25, P. 111).

Means of Ratings of Importance of Factors to the Creative Scientist and Rank Orders of the Research Group and of a Non-research Group.

Code	Common Factor Name	Mean	Rank (research)	Rank (non-research)
DFT	Figural adaptive flexibility	6.4	1	2
CMT	Penetration	6.3	2	1
CMS	General reasoning	6.1	3	4
NST	Symbolic redefinition	5.6	4	8
NMT	Semantic redefinition	5.5	5	5
CFI	Perceptual foresight	5.0	6	7
NFT	Figural redefinition	4.8	7	9
EMI	Sensitivity of problems	4.7	8	11
CMR	Eduction of conceptual relations	4.7	9	14
EMR	Logical evaluation	4.5	10	16
CMI	Conceptual foresight	4.5	12	12
CSS	Eduction of symbolic patterns	4.5	12	17
CFT	Visualization	4.5	12	10
NMR	Eduction of conceptual correlates	4.3	14.5	13
DMC	Spontaneous flexibility	4.3	14.5	3
NMS	Ordering	4.0	16	20
DMI	Elaboration	3.9	17	19
DMT	Originality	3.7	18	15
DMU	Ideational fluency	3.6	19	6
CFR	Eduction of figural relations	3.5	20	18
MMU	Memory for ideas	3.3	21	23
CFS	Spatial orientation	3.1	22	21
CFC	Figural classification	2.9	23	24
NSR	Eduction of symbolic correlates	2.7	24	27
CMU	Verbal comprehension	2.7	25	25
ESR	Symbol manipulation	2.5	26	28
DMR	Associational fluency	2.1	27	22
EFU	Figural identification	2.0	28	26

The only factor similar to an intellectual quality, which was rated very low, was "Symbol manipulation" (= "Logic manipulations"). The factors "Originality" and "Ideational Fluency" also have very low ratings. Guilford explains this fact by stating that the definitions, especially those of the above factors, are rather biased and, therefore, susceptible to wrong interpretations. The rated positions of all other factors corresponding to the intellectual characteristics are fairly high, indicating that they are relatively important for the work success of scientists.

Although the interpretation of these findings is limited, they nevertheless show that some of the intellectual qualities described as being characteristic for the performance of mathematicians and engineers jobs were also found using other methods, and tend to confirm their importance for the successful work performance of scientists.

Another detailed comparison of the results of the study with other intelligence concepts does not appear to be necessary because it would only generate rather vague and general results. On the one hand, we would probably find similarities between factors and intellectual qualities, and that some factor definitions would differentiate between intellectual activities more clearly than the concepts derived from this study. However, on the other hand, problem-solving activities would probably be more clearly defined in this study than they are in other factor studies.

7.2.2. Comparison with findings of "Game Theory".

The importance of decisions and their relation to cognitive and personality characteristics was one of the major findings of this study (see P. 23). A comparison of these results with a different approach towards decision-making, might be useful in order to establish to what extent aspects of both approaches can be assimilated.

Decision-making and its implications is incorporated in the "Game Theory" approach (see 46 & 31). Probably due to the fact that "the logical analysis of games of strategy ... was undertaken not by psychologists but by mathematicians" (32, P. 129), the psychological implications of "games" have been neglected to some extent. This study, however, focuses on these psychological determinants of decision-making.

As regards this particular aspect of decision-making, some of Rapoports observations and conclusions which are of interest here are based on the analysis of mathematically constructed games. He states that "there is a hierarchy of levels of decisions and the concept of rational decisions becomes progressively more dependant on specific psychological or even ethical hypothesis as we pass to the more complex levels of decision problems (32, P. 130).

The same conclusions were also drawn from the results of this study, where it was found that the characteristics of decisions involved in jobs of a fairly simple nature are rational manipulations and evaluations, while more complex jobs imply

what Rapoport probably considered as "psychological factors", viz. "judgmental confidence, readiness to take responsibility for far-reaching consequences," etc.. These findings are also to some extent supported by N. Jordan (28) who interprets Game Theory, and decision-making in terms of "Gestalt" psychology. He emphasized the fact that "psychological certainty" is important in the process of deciding and defines "psychological certainty" as the functioning "of an organism in a confident and assured manner" (28, P. 134). Rapoport further states (28, P. 139) that "the principal advantage of the game method" (and with it the simulation of decision-making) "lies in the circumstance that, while the thought processes so tapped are quite rich in psychological content...".

Similar deductions were drawn in this study when stating that (P.23) "in fact we find that nearly all intellectual qualities as described in the Categories can be deduced from the kind of decisions which are made on the different job levels."

The comparative results with other intelligence concepts can, therefore, be summarized as follows:

(i) Intellectual abilities from Guilford's structural intelligence model, which were rated as important for the work success of scientists, were also suggested by this study although differences with regard to the degree

of differentiation between several intellectual abilities could be established.

(ii) The importance of "decisions" and their relation to cognitive and personality characteristics revealed by this study, was supported by conclusions derived from mathematical and "Gestalt" psychological decision models of "Game-theory".

8. Conclusions and Recommendations.

8.1. Practical Aspects.

(i) The categories of intellectual characteristics.

On the basis of the findings as indicated by the first two categories of intellectual characteristics which involve primarily cognitive processes, and those of the third category indicating the importance of the affective and personality characteristics in job performance, a differentiation of selection methods for research personnel appears advisable.

The emphasis of the selection of junior research personnel should be laid on the identification of cognitive or intellectual abilities. The selection of senior research personnel should emphasize, however, the testing of personality aspects (e.g. emotional stability, selfconfidence, sociable willingness and, more generally, leadership qualities). This implies that in the actual selection process, personality tests and/or projective techniques should be used. It also appears that the introduction of

methods such as group-discussions should be considered seriously, particularly where the assessment of leadership is required.

The intelligence tests used at present for the selection of senior research personnel is not sufficiently differentiating. Another point arising from this study, is that work achievement on higher levels is largely dependant on the knowledge and experience of incumbents, which cannot be tested easily or evaluated by the psychologist.

Although not directly related to personnel selection procedures, some further conclusions concerning personnel management problems can be drawn from the "categories".

Categories I and II (which include A.R.O.'s R.O.'s and S.R.O.'s) constitute a transition of tasks from "simple" application of research methods to a more sophisticated use of research methodology, while category III (Divisional Head-level and higher) involve demands and functions which are completely different from those of the first two categories. Without any previous training for the execution of these new functions (e.g. "thinking in organizatorial contexts, learning administrative 'skills' ") a transfer of incumbents from basically pure research activities to a new field of work must create difficulties for the persons concerned as well as for the division. By gradually introducing incumbents (who are likely to be promoted as Divisional Heads) into their new field and/or by training them in e.g. handling administrative matters, these difficulties could be reduced.

(ii) Decision-making and its simulation.

The implications of decision-making and their

relationship to game theory have already been discussed (Chapter 7.2.2). The conclusions drawn from this discussion support P.R. Skawran's (38) recommendation to use "games" as e.g. Frederiksen's "In-Basket Test"(20) for the selection of high-level research personnel.

It seems, however, that a clearer definition of what the "In-Basket Test" measures in terms of the quality of the decisions is needed. The ability to make decisions is - as has been emphasized by P.R. Skawran (38), Rapoport (32) and N. Jordan (28) - determined by various factors, e.g. cognitive and emotional factors. Before using any "game" or method of simulating decisions, it is, therefore, advisable to determine the processes or characteristics which are prominent in the act of deciding.

Studies which relate the results of "games" to personality and intelligence tests are, at this stage, pre-eminent to the practical application of the simulation of decision processes for specific selection purposes (e.g. selection of research management).

Another specification of "games" for the assessment of research management becomes apparent when constructing decision situations simulating this activity. Simply to simulate decision processes seems to be too global! It is evident from J.N. Fairhead's, D.S. Pugh's and W.J. William's investigation (16), that a more structurized approach to the drawing up of decision exercises is possible. They developed six games for different fields of management, viz. Production Planning, Marketing Management, Personnel Management, Supervisory Management, Executive Management and Top Management. It is suggested to consider such an approach more seriously with regard to the development of a "Research Management Exercise".

8.2 Theoretical aspects.

The following conclusions and recommendations with regard to an improvement of methodological aspects of investigations on intelligence of research workers stem from W.A. Scott and M. Wertheimer's (37, P. 101) statement that "a qualitative measure can be seen as a first crude attempt to define a variable, which can perhaps subsequently be assessed with greater precision". Firstly, an analysis of the underlying methodological principles of this study suggests that it is possible to devise additional and more structured approaches. The application of the N.I.P.R. job description method to the problem of intelligence, can be considered as a means of stimulating interviewees to introspect and subsequently to describe "self-perceived mental processes". Explanations of these mental processes formed a basis for the establishment of the "Categories of Intellectual Characteristics."

Although not mentioned as such, this concept of introspection is incorporated in many psychological investigations. "It is still doing its business under various aliases" (Boring(6, P. 169)). For instance, early research on "Creativity", was strongly marked by the application of introspection (See Hadamard (26), Eiduson (10), A. Roe (34) and J. Rossman (33). Similarly, in this study, it was the primary means of generating information. Assuming that the precision of a methodical concept used in a psychological study should be a function of its importance, it appears to be necessary to improve the procedure of "self-perception of mental activities", so that it can be used as a more concise basis for a job-orientated approach towards intelligence.

An improvement can only be affected in the form of a synthesis between qualitative and quantitative methods of research as proposed by A.O. Jaeger (27, P. 4f.), with

regard to intelligence research. He underlines the necessity for a synthesis between "process research" (i.e. research on the process and conditions of thinking - as it was partly done in this study) and "dimensional research" (e.g. correlative and factor analytic methods), which starts "where the 'process research' ends: viz. with the analysis of the results of thinking processes." Possibilities for the application of Jaeger's concept have been suggested by French (20), and later Ertel (14, 15). Ertel's investigations are probably the most advanced since he has overcome some of the methodological difficulties experienced by French and has extended Witkin's (47, 48, 49) concept. Therefore, Ertel's studies can be used as a basis for a more structured approach in identifying thinking processes (and their results) related to the job performance of research workers. In order to clarify the new concept it is necessary to delineate the methods he used and to explain his major findings.

In an attempt to clarify the mental processes involved in test-performance, Ertel (14), developed a new variant of Osgood's "Semantic Differential" (later called: Test Behaviour Differential), where subjects were required to scale the intellectual processes involved in their test-performance. The results of his various studies (see also Ertel (12, 13)), based on this concept can be summarized briefly as follows:

(i) A method, using the test-behaviour differential, has been developed to analyse the thinking processes involved in problem-solving.

(ii) Three "dimensions of cognitive behavior" (i.e. factors), have subsequently been identified: Exertion (less vs. more), Variability (flexible

spontaneous vs. steady systematic), Unification (global, structuring, vs. elemental, analytic, diversifying). These dimensions were identified in several investigations with different groups of subjects, and under varying conditions. The dimensions were interpreted to represent basic variables of intellectual behaviour relatively independent of the situation and the population.

(iii) Individual problem-solving styles could be identified by measuring the extent to which subjects used these dimensions of cognitive behaviour in coping with test-problems. The influence of these individual problem-solving styles on test-achievements could be assessed.

Since the results of Ertel's studies attempting to analyse the processes and dimensions of cognitive behaviour are encouraging, his test behaviour differential can be applied in a specific way, viz. instead of using tests as objects for scaling the intellectual processes, "typical work situations" (i.e. critical incidents) can be used.

Using this basic concept, the following problems can be investigated:

(i) The identification of "professional problem-solving styles". The extent to which each of the three dimensions of cognitive behaviour are used in different occupational groups could give an indication of whether it is possible to differentiate between different modes of thinking which are typical for certain occupations and which are necessary for the performance of groups of jobs.

(ii) The relationships between "professional problem-solving styles" and work success.
An identification of the professional problem-solving styles related to either high or low work performance would be valuable for the specification of selection procedures because predictors which measure those problem-solving styles necessary for work success could be selected and/or devised.

(iii) The relationships between professional problem-solving styles, work success and test-achievements.
A comparison of these three problem areas should give an answer to the following questions:

(a) To what extent do the present intelligence tests predict work success?

(b) To what extent can work-success and test achievements be explained in terms of professional problem-solving styles?

(c) To what extent can the differences in test-achievements of different occupational groups be explained in terms of professional problem-solving styles.

It is suggested to implement the proposals as follows:

(i) The selection of Institutes and groups of research workers who will participate in the investigation. This selection should be based on clear definitions of occupational groups which differ with regard to education and the kind of work performed. A differentiation between Biologists, Chemists, Physicists and Engineers might be fruitful. Each sample should include at least 50 subjects.

(ii) An evaluation of the job performance of research personnel participating in the study. Flanagan's (19) questionnaire concept is proposed for this evaluation. The application of this method necessitates the rating of the activities of sub-ordinates by their superiors over a period of six months. Superiors would use the "Critical Incident Report-Form" for their ratings and at the end of six months they would summarize their observations in the "Performance Evaluations of Research Personnel" form.

(iii) Once their job performance has been evaluated, the research workers involved should use a variant of Ertel's Test-Behaviour Differential to scale the intellectual processes used by them in the activities described on their "Critical Incident Report" form.

8.3. N.I.P.R. Job-Description Method.

The N.I.P.R. job description and analysis method provided a useful basis for this study, especially in discriminating between jobs of different complexities. In addition the "Grade" definitions seem to circumscribe all important aspects of groups of jobs on different levels. However, with regard to the interpretation of the "Grades" as a means for the identification of "the intelligence" necessary for the performance of jobs, the N.I.P.R. job description method has its limitations.

It is suggested to adapt the N.I.P.R. job description method in such a way, that it provides information relevant to the construction of the proposed "Research Management Exercise". This suggestion takes into account that the N.I.P.R. job description method uses interviewing techniques which are suitable for compiling detailed information on the decision processes forming an essential part of the research management jobs.

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ANNEXURE

Scale Definitions of the Job Evaluation Factors.

1. Scale definitions of the Factor - "Decisions".

1. Limited number of clearly defined alternatives (e.g. to design a circuit with an open loop amplifier or a closed loop amplifier), where the most suitable one is selected. Decisions are characterized by relating demands of task with its well defined experiment specifications (e.g. specifications of electronic components, computer prescriptions etc.) to own factual knowledge (e.g. university knowledge on basic electronic principles, etc.) and/or limited experience (e.g. experience on quality of components, etc.). Acts on clear-cut cues. The correctness of a decision is immediately established as a result of feed-back of information from own experimental work (e.g. failing units of electronic circuits lead to alterations of the circuit), the availability of laws/principles and limited applied experience.

   1i

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2. Alternatives are frequently less clearly defined, some of them tentative for short-term trial, and solutions to a given problem (e.g. how to overcome d - c shifts, etc.), have to be devised. Decisions are characterized by collecting and comparing information (e.g. descriptions of different apparatus, etc.) and interpreting it in terms of the purpose and needs of work (e.g. growth of semiconductors, etc.). Guided by logical deductions and analysis based on knowledge and experience in a specific field (e.g. own experimental set-ups and calculations are used in order to find cues for decision). Responsibility for small projects is usually allotted to incumbent.

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3. Multiple interrelated alternatives are evaluated and compared in terms of the wider applicability of their underlying principles. Alternatives are developed in the form of original solutions (e.g. completely new circuit design). Decisions are characterized by the accumulation and evaluation of information, reducing it to its fundamental characteristics and by the application of newly gained insight into unfamiliar problems in a given field. Guided by cues obtained from the analysis of alternative solutions, systems, approaches and the recognition of their interrelations and implications, particularly when planning projects. In his decision, he is also guided by more general considerations regarding the time and cost of a project, its usefulness, budget restrictions, etc.. Responsibility for own projects, as well as projects of subordinates, which requires consideration of the consequence of error.

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4. Variety of different and interrelated alternatives (few of them predetermined), consisting primarily of complex and interrelated systems and basic approaches (e.g. new education systems for technicians, etc.).
Decisions are characterized by the need for anticipating and planning new research policy, etc. and integrating research efforts with visualized objectives which will benefit the Institute and the Nation. Does this on the basis of following up subtle and unprecedented cues, indicating new trends and needs for development (e.g. future computer services in S.A.). Also necessitates integration and reconciliation of conflicting factors (e.g. needs of Divisions, Institutes, demands of Industry, etc.).

2. Scale definitions of the Factor - "Controls and Checks".

1. Detailed and regular control. Specific task instructions from superior. Incumbent checks on his own progress and quality of work, e.g. by noticing the malfunctioning of parts, incorrect calculations, etc., and immediately applies the necessary corrections himself. On completion submits results to superior. Consequence of error practically nil.

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2. More general instructions and irregular control of research techniques and procedures in a number of tasks by superior. Recognition of own mistakes and their correction requires technical interpretation, but incumbent can consult others. Quality of work is checked by the general success of completed tasks. Consequence of error means repeating the task/s and some loss of time.

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3. Controls primarily in form of approval or rejection of own project proposals by discussion with superior and specialists. Quality of work is checked more indirectly (apart from budget and time expenditure) by final reports, customer's appreciation and the acceptance of research results for publication. Mistakes may have negative effects on image of Division or Institute.

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4. Controlled by formal approval of proposals for several projects (in a particular research area) which are evaluated by specialists, experts and committees. Responsibility for the direction, co-ordination and completion of projects lies with incumbent. Quality of work is checked by final success of projects, as well as by the impact of incumbent's publications. Mistakes decrease efficiency and progress of work of the Division and Institute and may have negative effects on the image of the latter and of the C.S.I.R.

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5. Determines scientific and industrial developments, e.g. utilization of computer science or personnel mangement, etc., although scientific bodies and advisory committees have to give formal approval. Initiative for these developments emanates primarily from the incumbent. Quality of work is controlled indirectly by national and scientific approval of services rendered. Consequence of error may have negative effects on research developments with regard to the Institute as a whole, the C.S.I.R. and the country.

3. Scale definitions of the Factor - "Contact with People".

1. Contact within the section, i.e. with colleagues and superior. Contact primarily in terms of specific instruction, guidance and advice on specific tasks and queries which incumbent may have in this respect. Usually on an individual basis.

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2. Contact with people within division usually in terms of more general instruction and advice on smaller projects and some discussion with colleagues and specialists to obtain advice. Occasionally has to discuss a technical problem with laymen, on the basis of specific experience. Still primarily on an individual and informal basis, although some group discussions may be attended.

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3. Contact with people within the Institute, as well as with some clients, primarily in the form of discussions to obtain advice, clarification and, at times, to persuade others. Could also involve supervisory functions over a limited number of junior colleagues. Contacts becoming more formal by participating in discussions and meetings concerning own specialized field of knowledge.

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4. Contact with divisions, institutes, clients and scientific and management bodies. Contacts both formal and informal as well as on individual, personal and group basis. Emerging more clearly in a research leader capacity, conveying critically, evaluating, discussing and convincing people in own field as well as in other fields. Also dealing with organizational and management problems, e.g. behaviour of groups and reconciliation of conflicting views.

4. Scale definitions of the Factor - "Language Usage".

1. Familiarity with specific technological terminology pertaining primarily to own field of work. Verbal and written reports where facts of own work are described.

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2. Familiarity with specific technical terminology and interpretation of technological information related to own work and the work of Division. Writing of short reports (pertaining to own work) on general lines of action, where technical language is transformed into popular language and/or own opinion is expressed during meetings or informal discussions with customers. English and Afrikaans is necessary.

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3. Immediate understanding of technical information (condensed or otherwise), by distinguishing the important from the unimportant, recognizing essential aspects and the underlying principles of written and verbal matters. Clear, concise and fluent expression in writing publications (and work reports), addressing public meetings. Formal discussions with senior people. Convincing by logical presentation of technical facts. Some foreign languages are necessary.

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4. Immediate grasping and conceptualizing of essential aspects regarding technical and general information and detecting subtle points and "under-currents", (e.g. reading between the lines). Quick, concise and fluent formulation of own answers,

objections and proposals. Is logical and systematic with regard to written and verbal matters and uses rhetorical techniques in order to convince people. Some foreign languages are necessary.

5. Scale definitions of the Factor - "Experience".

1. No specific experience, i.e., apart from his academic training required. Typical "beginner jobs" where incumbents are introduced and trained in clearly circumscribed tasks, (applying a limited number of techniques) usually forming only part of a field, e.g. programming.

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2. Learning to put into practice and to apply techniques self-reliantly (e.g. Variance Analysis). Learning of new but basic principles (e.g. computer languages) and applying them. Becoming familiar with the manipulation of apparatus, and becoming skilled in the use of instruments, etc., in order to facilitate and accelerate work.

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3. Accumulation of knowledge and experience in a variety of techniques in order to obtain "insight" into technological and/or scientific problems in a given field. Problem consciousness is developed and difficulties of work (e.g. behaviour of equations under certain conditions) are recognized and anticipated. New situations are handled fairly expertly by the drawing up of analogies between the performance of former tasks and the actual work problems, leading also to the formulation of hypothesis and theory. Comprehending and explaining results of research work in a concise and logical form. Learning to work independently on research projects. Learning to handle others and to supervise staff so that incumbent can deal efficiently

with a variety of people.

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4. Learning to handle organizational and administrative matters, e.g. estimating time and cost of projects, and operating in organizational contexts (e.g. determine priorities of projects). Acquaintance with managerial aspects of work by gaining insight into commercial and industrial procedures, their shortcomings and research needs. Capability to bear responsibility for staff and develop techniques to guide subordinates. Getting acquainted with representative aspects of work, i.e. taking part in meetings, and speaking in public where rhetoric techniques are applied. Efficient writing and speaking, so that one can negotiate successfully.

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