SA Journal of Industrial Psychology, 2002, 28(2), 55-66
SA Tydskrif vir Bedryfsielkunde, 2002, 28 (2), 55-66

CONSTRUCTION OF A COMPUTERISED INFORMATION-PROCESSING TEST BATTERY

JOHANN M SCHEPERS
Programme in Industrial Psychology
Department of Human Resource Management
Rand Afrikaans University

ABSTRACT

The primary goal of the study was to construct a computerised information-processing test battery to measure choice reaction time for up to and including six bits of information, to measure discrimination reaction time with regard to colour patterns and form patterns, to measure rate of information processing with regard to perceptual stimuli and conceptual reasoning, and to develop a suitable scoring system for the respective tests. The battery of tests was applied to 58 pilots. In order to develop an appropriate scoring system for each of the tests, the various scores (trials) were intercorrelated, and where necessary, subjected to factor analysis.

OPSOMMING

Die hoofdoel van die studie was om 'n gerekenariseerde inligtingverwerkingstoetsbattery te konstrueer om keusereaksietyd tot en met ses bis inligting te meet, om diskriminasie-reaksietyd ten opsigte van kleurpatrone en vormpatrone te meet, om tempo van inligtingverwerking ten opsigte van perseptuele stimuli en konseptuele redenering te meet en om 'n gepaste nasienstelsel vir die onderskeie toetse te ontwikkel. Die battery toetse is op 58 vlieëniers toegepas. Ten einde 'n gepaste nasienstelsel vir elk van die toetse te ontwikkel, is die verskillende tellings (beurte) met mekaar geïnterkorreleer, en waar nodig, aan faktorontleding onderwerp.

All external information reaches us via our senses. The incoming information must be processed as quickly and effectively as possible, and suitable decisions must be taken accordingly. In order to carry out this function effectively we depend on our senses and higher intellectual abilities. It would therefore be reasonable to postulate certain relations between measures of information processing on the one hand and cognitive abilities on the other hand.

As far as we know, Sir Francis Galton (1883) and James McKeen Cattell (1890) were the first to suggest that measures of reaction time be used to gauge intelligence. However, their studies were doomed to failure for methodological and psychometric reasons. But with the development of modern computers, the methodological problems were surmounted. And in the psychometric field, there is now a wide variety of techniques to analyse the relevant information. There are also various well-developed tests of intelligence available for use in studies in this field.

Jensen and his co-workers were some of the first researchers in the US to investigate the relation between reaction time and intelligence afresh. In a study of 39 standard seven (grade 9) girls, Jensen and Munro (1979) found a multiple correlation of 0,66 ($p < 0,01$) between five reaction time measures and the corresponding movement times on the one hand, and Raven's Standard Progressive Matrices (1947 edition) on the other hand. The five reaction time measures represent reaction times in respect of 0, 1, 2, 2,58 and 3 bits of information respectively.

With the exception of some research participants, the relation between reaction time and bits was linear for individuals. The average Pearson correlation between reaction time and bits was 0,97. This correlation represents a virtually perfect linear regression of reaction time on bits of information, which is in strong support of Hick's Law (1952), which postulates that there is a **rectilinear relation** between reaction time and amount of information, measured in binary digits (bits). The average Pearson correlation between movement time and bits of information was 0,54. An interesting finding here was that the average Pearson correlation between reaction time and Raven's Standard Progressive Matrices was –0,41 ($p < 0,01$), whereas the corresponding correlation with movement time was –0,46 ($p < 0,01$).

Cohen and Shelly (1982) refer to a series of studies conducted by Chris Brand of the University of Edinburgh, who used a series of visual and auditory discrimination tasks, and correlated the reaction times with a standard intelligence test. According to Cohen and Shelly, Brand found a correlation of –0,76 between discrimination time and IQ. However, no information is provided about the sample used.

Jensen et al. (1981) studied 54 seriously retarded adults with the aid of 15 psychometric tests. They calculated, *inter alia*, an index of **neural adaptability** on the basis of the average auditory evoked potential of the brain and, with the aid of factor analysis, they calculated a factor score in respect of "g", utilising the 15 psychometric tests. Reaction time and movement time were determined with regard to 0, 1, 2 and 3 bits of information. They obtained a multiple correlation of 0,64 ($p < 0,001$) between the measures of reaction time, movement time and neural adaptability on the one hand, and psychometric "g" on the other hand.

An interesting finding of this study was that Jensen et al. could not find any support for Hick's Law pertaining to the group of seriously retarded adults.

In a study of 58 unskilled American workers, Sen and Jensen (1983) found a multiple correlation of 0,43 ($p < 0,01$) between reaction time and movement time on the one hand, and Raven's Standard Progressive Matrices on the other. This correlation shrinks to 0,36 ($p < 0,05$) if the effect of chronological age is cancelled out.

An important finding of this study was that Hick's Law (1952) held for both individuals and group averages. It should, however, be noted that the reaction times were determined only for 0, 1, 2 and 3 bits of information. The reason for this is that Jensen's apparatus was limited to a maximum of 3 bits of information.

The question that arises is whether the findings of Jensen and his colleagues can be generalised to groups with above-average and

Requests for copies should be addressed to: JM Schepers, Programme in Industrial Psychology, Department of Human Resource Management, RAU, PO Box 524, Auckland Park, 2006

even superior abilities. Without further information, one might reach the conclusion that his findings are a function of the undifferentiated intellect of his research participants.

Cohn, Carlson and Jensen (1985) did a comparative study of 70 above-average standard 5 (grade 7) pupils and 60 academically highly gifted pupils. The mean age of the above-average group was 13,17 years and that of the highly gifted group 13,5 years. The two groups did not differ statistically significantly in respect of average age. The highly gifted group represented the top 2% – 3% of the public school population with regard to academic aptitude, and performed well in university courses in mathematics and science. The above-average group was not selected with regard to academic aptitude, but came from a junior high school in a white middle and upper class environment.

Raven's Standard Progressive Matrices and nine different reaction time tasks were applied to all the research participants. The reaction time tasks measure the speed with which people carry out various elementary cognitive processes. The regression of the reaction time tasks on Raven's Standard Progressive Matrices was calculated and yielded a multiple correlation of 0,60 for the highly gifted group, and 0,50 for the above-average group.

Another interesting finding made by Cohn et al. was that, with the help of discriminant analysis, they could correctly classify 91,7% of the highly gifted group and 76,4% of the above-average group by using only eight of the reaction time tasks. The highly gifted and above-average group differed on average by 1,3δ on the different reaction time measures, in comparison with 1,9δ on the measure of psychometric intelligence, namely Raven's Standard Progressive Matrices. Therefore, it seems that in addition to higher intellectual abilities, the highly gifted group demonstrated a much higher rate of information processing than the above-average group.

In view of this, it is evident that there is a need for suitable instruments for measuring choice reaction time, discrimination reaction time and rate of information processing. Such instruments could be used in research on attention, psychometric intelligence, the evoked potential of the brain, accident proneness, and in the selection of pilots.

In the sixties Schepers constructed two tests of information processing for the South African Air Force. A brief description of these tests by Schepers (1970) can be found in the book entitled: "Sielkundige meting: Huidige status in Suid-Afrika". A fuller description thereof is appropriate here.

To measure Rate of Information Processing Schepers (1970) used the silhouettes of 18 imaginary aircraft. The silhouettes are presented serially and randomly, with the aid of a special projector (perceptoscope), at an increasing rate. The research participants must classify the silhouettes according to prescribed rules. Their responses are registered by means of a tape recorder, which also serves as communication channel.

The test comprises two parts, namely Rate of Information Processing (Perceptual) and Rate of Information Processing (Conceptual). Each part consists of six series, and each series consists of 18 trials. The same 18 silhouettes are used throughout, but are presented randomly within each series.

The silhouettes can be differentiated in terms of type of nose, type of wing and type of tail. There are three types of nose, namely pointed, round and square. There are three types of wing, namely straight, swept backwards and delta shaped. And there are three types of tail, namely straight, swept backwards and delta shaped. Therefore, there is a total of 27 possible silhouettes (3^3). A selection of 18 silhouettes was used for the purposes of the test.

In the first part of the test, the research participants must decide only whether the type of wing matches the type of tail. Their judgement is thus purely of a perceptual nature. Each subsequent series is presented at a higher rate.

In the second part of the test, two types of fighter aircraft are defined, namely a FIN (belonging to the Navy), and a FOOT (belonging to the Army). The research participant must decide whether the silhouette that is presented is a FIN or a FOOT.

A FIN has a square or round nose, and matching wings and tail

OR

A pointed nose, and wings and a tail that do **not** match.

The codename for all other aircraft is FOOT.

The definitions of a FIN and a FOOT are fairly complex and use the logical operators **and**, **or** and **not**. Therefore, the information that must be processed is of a conceptual nature.

The research participants are given ample opportunity to learn the defining attributes of a FIN and a FOOT before the test begins.

In the first part of the test, every silhouette is visible for 0,1 seconds. In the second part, the exposure time is 0,75 seconds.

The total time available for observation, decision-making and responding, for every series, is given in Table 1.

TABLE 1
TOTAL TIME FOR EACH OF THE SERIES

Part	Series	Total time
1	1	2,00 sec.
1	2	1,70 sec.
1	3	1,50 sec.
1	4	1,30 sec.
1	5	1,20 sec.
1	6	1,10 sec.
2	Practice trial	8,25 sec.
2	1	7,50 sec.
2	2	5,25 sec.
2	3	4,13 sec.
2	4	3,38 sec.
2	5	3,00 sec.
2	6	2,63 sec.

In order to investigate the attributes of trainee pilots, Schepers (1987) applied an extensive battery of psychometric tests to 207 prospective trainee pilots. All the research participants were in possession of a certificate of general matriculation exemption, including mathematics and science as matric subjects. The test battery consisted of 46 psychometric and neuropsychological tests, measuring the following constructs, among others:

- Information processing of a **perceptual** nature
- Information processing of a **conceptual** nature
- Intelligence
- Neuropsychological stability-instability
- Introversion-extroversion
- Respiration rate

- Haptic perception
- Dark adaptation
- Heart-rate
- Field independence

The battery is too large to give a full description of every test here. Interested readers are referred to a later work by Schepers (1970) entitled "Sielkundige Meting: Huidige status in Suid-Afrika", which gives fairly comprehensive descriptions of most of the unknown tests that have been used.

Since the sample consisted of 121 Afrikaans-speaking participants and 86 English-speaking participants, it was decided to determine the factor structure of the test battery with the aid of inter-group factor analysis (Meredith, 1964a and 1964b).

Eleven factors were extracted and rotated to simple structure with the aid of a Promax rotation. Only the factors pertaining to the Information Processing tests will be discussed here:

Factor 1 had high loadings on all six series of Rate of Information Processing (Conceptual), but on none of the other variables. Factor 2 had high loadings on all six series of Rate of Information Processing (Perceptual) and on **three** embedded figures tests, namely Thurstone's Designs Test, Gottschaldt Figures, and Witkin's Embedded Figures Test. Factor 4 had high loadings on Mental Alertness, Arithmetic Problems, Technical and Scientific Information, and Technical Reading Comprehension. It also had moderate loadings on the Designs Test, Word Fluency Test, Gottschaldt Figures, Witkin's Embedded Figures Test and the Rod and Frame Test. Therefore, this factor could be interpreted as general intelligence.

Factor 1 had a moderately high correlation with Factor 2, and a moderate correlation with Factor 4 (general intelligence).

The reliabilities of the two Rate of Information Processing Tests were calculated with the help of Kuder-Richardson Formula 3:

$$KR_3 = \frac{S_x^2 + \sum S_g^2 r_{gg} - \sum S_g^2}{S_x^2}, \text{ where}$$

S_x^2 = variance of total score;

$\sum S_g^2$ = sum of variances of each series, g;

r_{gg} = reliability of each series, g.

The reliability of each series was estimated on the basis of their respective communalities.

According to Kuder-Richardson Formula 3, the reliability of Rate of Information Processing (Perceptual) was 0,788 and that of Rate of Information Processing (Conceptual) was 0,929. These coefficients were calculated in respect of the English sample.

It appears from the above that the two tests of Rate of Information Processing look promising for further development. However, the apparatus (perceptoscope) that was used is very clumsy and unreliable for routine testing. The task would have been carried out far more effectively with the help of a computer. Such an apparatus was recently developed at RAU. It is described fully by Shaw and Schepers (1988).

Objectives of the study

The current study had the following objectives:

- To measure choice reaction time for up to and including six bits of information.
- To measure discrimination reaction time with regard to colour patterns and form patterns.
- To measure rate of information processing with regard to perceptual stimuli and conceptual reasoning. These tests were, in essence, constructed according to the rationale of Rate of Information Processing (Perceptual) and Rate of Information Processing (Conceptual).
- To develop a suitable scoring system for the respective tests.

METHOD

Sample

This study used data collected by Barkhuizen (2001), who applied the Computerised Information Processing Test Battery to 58 pilots. Because of limited access to pilots and limited testing time, he used a **sample of convenience**.

The sample was stratified according to age, years of flying experience, flying hours and type of aircraft flown. The average age of the pilots was 28,72 years and the standard deviation was 7,78 years. The ages ranged between 21 and 50 years. The average years of flying experience was 8 years and the standard deviation was 15,69 years. The years of flying experience ranged between 1 year and 26 years. The average number of flying hours was 1 810 hours and the standard deviation was 2 010,72 hours. The flying hours ranged between 300 hours and 9 000 hours. The average number of hours flown with a specific type of aircraft was 327,95 hours and the standard deviation was 2 277,42 hours. The number of flying hours flown with a specific type of aircraft ranged between 12 hours and 3 000 hours. The types of aircraft flown were the following: Lockhead C130, Cessna Citation, Hawker Siddeley, King Air, Cessna Caravan, Cessna 182, Casa 212, Oryx and Allouette helicopters. The minimum academic qualification of the pilots was matric with mathematics and science as subjects. The highest qualification was a master's degree. There were 53 men and 5 women in the sample.

Measuring instruments

The Computerised Information Processing Test Battery consists of the following chronometric tests:

1. Choice Reaction Time;
2. Discrimination Time (Form);
3. Discrimination Time (Colour);
4. Rate of Information Processing (Perceptual); and
5. Rate of Information Processing (Conceptual).

Since the **computerised system** has already been described in full (see Shaw and Schepers, 1988), it will not be repeated here. The reader should, however, note that the **interactive screen** used in this study is touched by the research participant with his index finger, instead of with a light pen, as previously described.

A brief description of each of the chronometric tests will now be provided. The task will be described every time with reference to a **test instruction**, followed by technical details about the specific test:

Test 1: Choice Reaction Time

Instructions

This test measures your ability to react **quickly** and **accurately** to simple visual stimuli.

You must keep your hand on the table throughout the test, in the space indicated as **hand**. You may only raise your hand when responding.

A warning signal in the form of a **red dot** will appear on the screen in front of you. **One second** later it will disappear and in the place thereof a configuration of **red** lights will appear. A moment later one of the lights will change into **green** and then you must **immediately** touch it with your index finger. The moment you touch the screen the configuration of lights will disappear. You must then immediately place your hand on the table again. The warning signal for the next trial will then appear and the process will repeat itself.

There are 11 different configurations altogether, and for each configuration there are 20 trials.

You will now be given **five trials** for practice, after which the test itself begins.

Place your hand on the table and pay attention to the screen. Wait for the warning signal and the configuration of lights to appear. Touch the light that turns **green** with your index finger. Work as **quickly** and **accurately** as you can. If you touch a wrong light it will turn **yellow**. However, this will only happen during the **practice trials**. Therefore make sure that you respond accurately.

Ready! Press the key indicated as **Begin** to start the trial run.

Choice Reaction Time
Technical details
A diagrammatic representation of the test procedure is given in Figure 1.

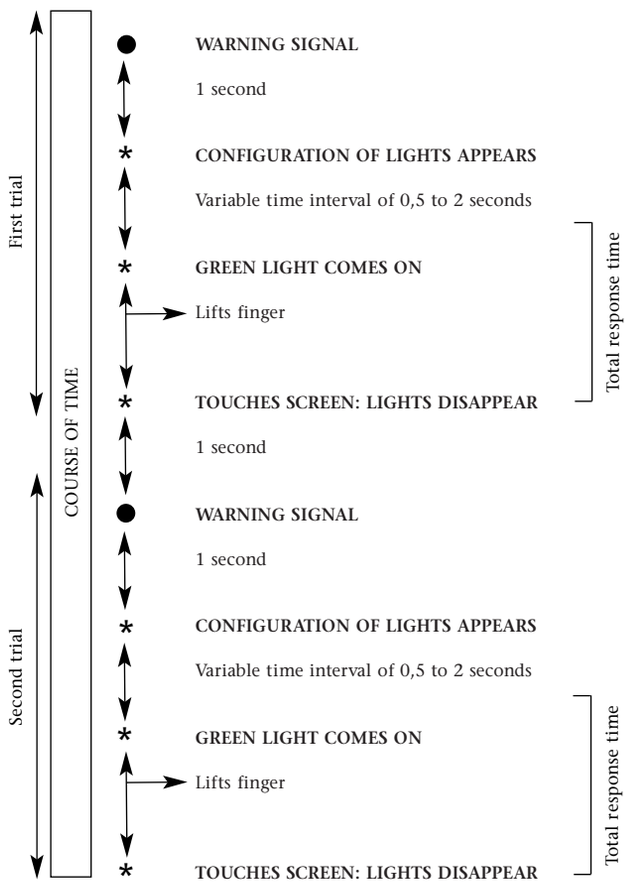


Figure 1: Choice Reaction Time

All the technical detail of the test is given in Table 2.

Table 2
Technical detail of choice reaction time test

Configuration	Numnber of lights	Bits	Number of trials
1	1	0	20
2	2	1	20
3	4	2	20
4	8	3	20
5	9	3,17	20
6	16	4	20
7	25	4,64	20
8	32	5	20
9	36	5,17	20
10	49	5,61	20
11	64	6	20

The 20 trials must be presented **randomly** by making use of **random numbers**. If there are two or more lights in the configuration, you must decide with the help of random numbers which one should light up.

The **time interval** from the moment that the configuration of lights appears until a specific light "lights up" green, must also be chosen randomly. An interval of 0,5 to 2 seconds can be selected. **Random numbers** must also be used here.

The configuration of lights must disappear as soon as the research participant touches the screen with his/her index finger. An error must be registered if he/she touches an incorrect light.

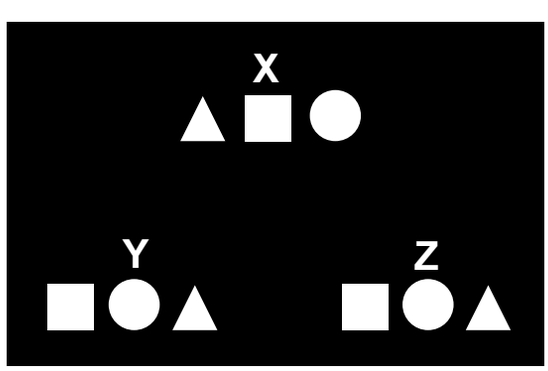
The time interval from the moment that a specific light "lights up" green, until it disappears must be registered. This represents the research participant's total response time for that trial.

Response times for each separate trial must be registered.

ACCURACY: 0,001 seconds.

Test 2: Discrimination Time (Geometric shapes)
Instructions
This test measures your ability to discriminate **quickly** and **accurately** between various **patterns of geometric shapes**.

A warning signal in the form of a red dot will appear on the screen in front of you. **One second** later a **blue dot** will also appear on the screen. The moment the **blue dot** appears you must place your index finger on it. The red dot will then disappear and a moment later a configuration of **geometric shapes** will appear on the screen. It will look as follows:



You must then compare the three patterns of geometric shapes, indicated as X, Y, and Z, and determine which pattern does not match the other two. You must then touch it with your index finger as fast as possible. In the case in question the pattern, X, does not match the other two. The moment you touch the pattern, the configuration of geometric shapes will disappear. You must then rest your hand on the table. The warning signal for the next trial will then appear and the procedure will repeat itself There are 30 trials altogether.

Do you have any questions?
You will now be given **five trials** for practice, after which the test itself begins.

Wait for the warning signal and the **blue dot** to appear. The moment the **blue dot** appears you must immediately place your index finger on it. The moment the configuration of geometric shapes appears you must touch the pattern that does not match the other two, with your index finger. But first decide which pattern does not fit before you react.

Ready! Press the key indicated as Begin to start the practice run.

Discrimination Time (Geometric shapes)
Technical details
A diagrammatic representation of the test procedure is given in Figure 2.

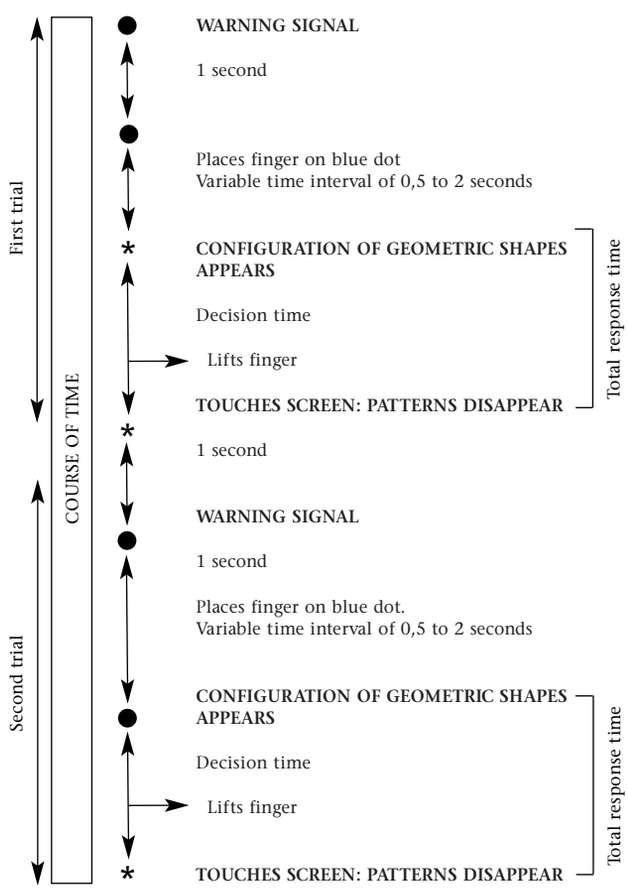


FIGURE 2: DISCRIMINATION TIME (GEOMETRIC SHAPES)

There are many similarities between this test and the previous one (CHOICE REACTION TIME). In fact, the sequence of presentation of the stimuli follows a similar pattern.

The test consists of 30 stimulus figures (predetermined), which must be presented **randomly** by using **random** numbers.

A warning signal (red dot) appears on the screen. One second later it turns into a **blue dot**. The research participant must immediately place his/her index finger on the blue dot. A moment later (0,5 to 2 seconds), a configuration comprising **three** patterns of geoemetric shapes appears on the screen. Two of the patterns are similar, but the third differs from the other two. The research participant must touch the pattern that differs from the other two as quickly as possible.

The time interval from the moment the blue dot appears till the configuration of patterns comes on must be chosen randomly by making use of random numbers.

The research participant's **decision time** is the time measured from the moment the configuration of patterns appears until the research participant **lifts** his/her finger.

The configuration of patterns must disappear as soon as the research participant touches the screen. An error must be registered if the research participant touches an incorrect pattern.

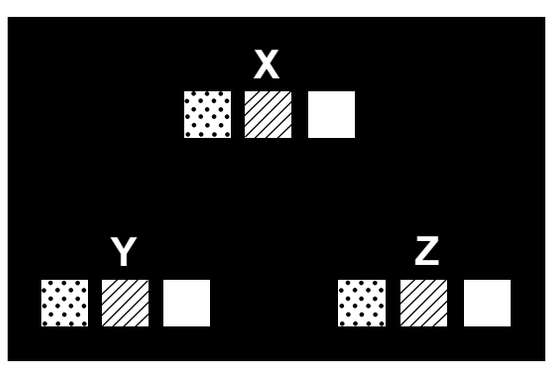
The time interval from the moment the configuration of patterns appears until it disappears must also be registered. This represents the research participant's **total response time** for that trial.

Response times must be registered for each separate trial.

ACCURACY: 0,001 seconds

Test 3: Discrimination Time (Colour)
Instructions
This test measures your ability to discriminate **quickly** and **accurately** between various **colour patterns**.

A warning signal in the form of a red dot will appear on the screen in front of you. **One second** later a **blue dot** will also appear on the screen. The moment the **blue dot** appears you must place your index finger on it. The red dot will then disappear and a moment later a configuration of colour patterns will appear on the screen. It will look as follows:



You must then compare the three colour patterns, indicated as X, Y and Z, and determine which pattern does not match the other two. You must then touch it with your index finger as fast as possible. In the case in question the colour pattern, Z, does not match the other two. The moment you touch the colour pattern, the configuration of patterns will disappear. You must then rest your hand on the table. The warning signal for the next trial will then appear and the procedure will repeat itself. There are 30 trials altogether.

Do you have any questions?
You will now be given **five trials** for practice, thereafter the test itself begins.

Wait for the warning signal and the **blue dot** to appear. The moment the **blue dot** appears you must immediately place your index finger on it. The moment the colour patterns appear you

must touch the pattern that does not match the other two, with your index finger. But first decide which pattern does not fit before you react.

Ready! Press the key indicated as **Begin** to start the practice run.

Discrimination Time (Colour)
Technical details
A diagrammatic representation of the test procedure is given in Figure 3.

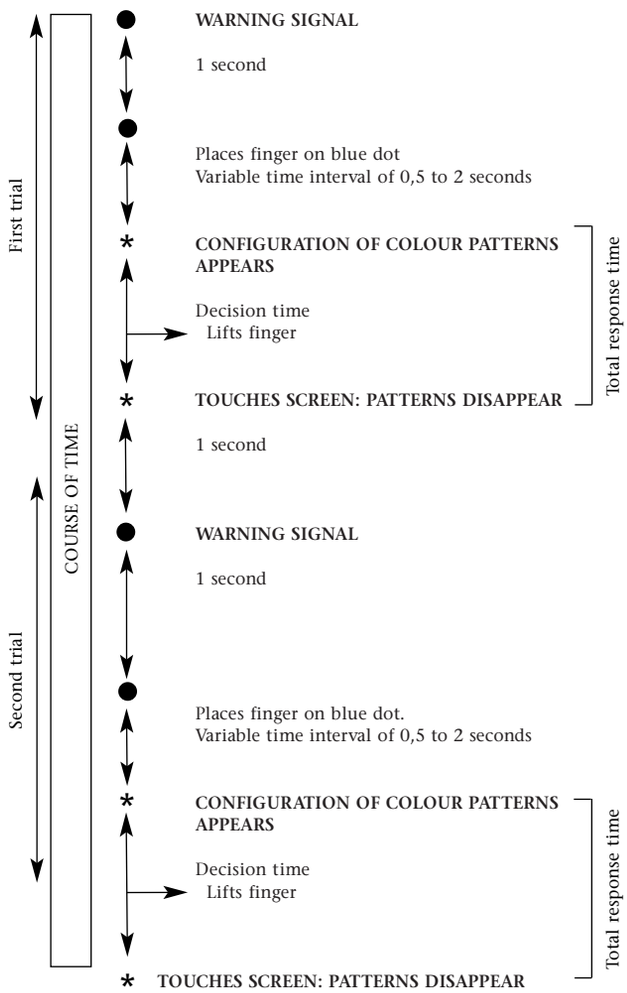


Figure 3: Discrimination Time (Colour patterns)

There are many similarities between this test and the previous one (DISCRIMINATION TIME: FORM). In fact, the sequence of presentation of the stimuli follows a similar pattern.

This test consists of 30 stimulus figures (predetermined), which must be presented **randomly** by using **random numbers**.

A warning signal (red dot) appears on the screen. One second later it turns into a **blue dot**. The research participant must immediately place his/her index finger on the blue dot. A moment later (0,5 to 2 seconds), a configuration of **three** colour patterns appears on the screen. Two of the patterns are similar, but the third differs from the other two. The research participant must touch the pattern that differs from the other two as quickly as possible.

The time interval from the moment the blue dot **appears** and the configuration of patterns appears must be chosen **randomly** by making use of **random numbers**.

The research participant's **decision time** is the time measured from the moment the configuration of patterns appears until the research participant **lifts** his/her finger.

The configuration of patterns must disappear as soon as the research participant touches the screen. An error must be registered if the research participant touches an incorrect pattern.

The time interval from the moment the configuration of patterns appears until it disappears must also be registered. This represents the research participant's **total response time** for that trial.

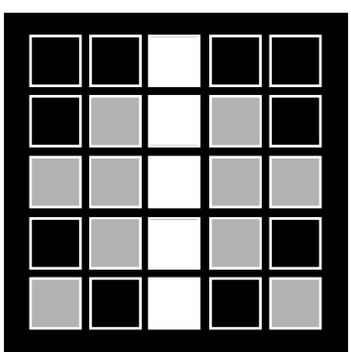
Response times must be registered for each separate trial.

ACCURACY: 0,001 seconds

Test 4: Rate of Information Processing (Perceptual)
Instructions
This test measures your ability to process **visual information** at a rapid rate.

A warning signal in the form of a **red dot** will appear on the screen, and **one second** later a stimulus figure will appear on the screen. The stimulus figure will be visible for only a fraction of a second and will then be extinguished. A moment later a new stimulus figure will appear. There are 30 stimulus figures altogether, and they will appear on the screen consecutively.

The following figure is an example of one of the stimulus figures:



The **vertical yellow column** represents a **line of symmetry**, and you must establish whether the stimulus figure that appears on the screen is **symmetrical** or not. If it is symmetrical you must touch the space on the screen indicated as Yes, with your index finger. If it is not symmetrical, you must touch the space indicated as NO.

The test consists of six series, each with 30 trials. The rate of presentation of the stimuli increases with each subsequent series.

Do you have any questions?

You will now be given five trials for practice, after which the test itself begins.

Wait for the warning signal and stimulus figure to appear. The moment it appears you must decide as fast as possible whether it is symmetrical or not. Then touch the appropriate space on the screen and wait for the next stimulus figure to appear.

Ready! Press the key indicated as **Begin** to start the trial run.

Rate of Information Processing (Perceptual)
Technical details
This test consists of **six series** and each series consists of 30 trials. There are 30 different stimulus figures (predetermined), which must be presented **randomly** within each series, by making use of random numbers.

A warning signal (red dot) is given, and the **first** stimulus figure appears **one second** later. The exposure time (tachistoscopic time) of each stimulus figure is **constant** throughout the test,

but should be adjustable between 0,1 and 0,5 sec. The experimenter must decide beforehand on the exposure time to be used. The time interval **between** the successive stimuli in each series is also **constant**, but must be adjustable from one series to the next. The following times are proposed for the six successive series:

OPTION NUMBER 1

Series	Rate
1.	One stimulus every 2,00 sec
2.	One stimulus every 1,67 sec
3.	One stimulus every 1,43 sec
4.	One stimulus every 1,25 sec
5.	One stimulus every 1,11 sec
6.	One stimulus every 1,00 sec

OPTION NUMBER 2

Series	Rate
1.	One stimulus every 1,00 sec.
2.	One stimulus every 0,83 sec
3.	One stimulus every 0,71 sec
4.	One stimulus every 0,63 sec
5.	One stimulus every 0,56 sec
6.	One stimulus every 0,50 sec

It is important to note that these times **include** both the interval between stimuli and the **tachistoscopic time**.

The research participant must decide whether or not the stimulus figure that is presented is symmetrical. If it is symmetrical, he/she must touch the space under the stimulus figure marked "Yes" with his/her index finger. If it is not symmetrical, he/she must touch the space marked "No" with his/her index finger. The spaces marked "Yes" and "No" must be visible throughout.

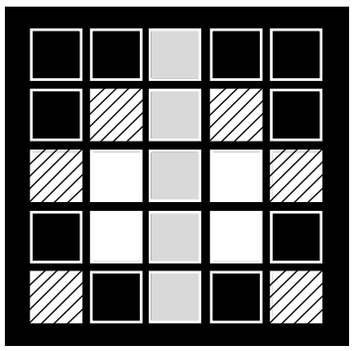
The research participant's score is the total number of correct responses, registered for all trials and series.

Use the first five figures for the practice exercise, but present them **randomly**.

TEST 5: RATE OF INFORMATION PROCESSING (CONCEPTUAL)
Instructions
This test measures your ability to process **visual information** at a rapid rate.

A warning signal in the form of a **red dot** will appear on the screen, and **one second** later a stimulus figure will appear on the screen. The stimulus figure will only be visible for a fraction of a second, and then it will be extinguished. A moment later a new stimulus figure will appear. There are 30 stimulus figures altogether, and they will appear on the screen consecutively.

The following figure is an example of one of the stimulus figures:



The **vertical green column** represents a **line of symmetry**, and you must establish whether the stimulus figure that appears on the screen is **symmetrical** or not **and** how many red blocks there are on a side. If it is **symmetrical *and*** the number of red blocks on a side is **not less than four or more than five**, you must touch the space on the screen indicated as **Yes**, with your index finger, otherwise you must touch the space indicated as **No**.

The test consists of six series, each with 30 trials. The rate of presentation of the stimuli **increases** with each subsequent series.

Do you have any questions?
You will now be given **five trials** for practice, after which the test itself begins.

Wait for the warning signal and **stimulus figure** to appear. The moment it appears you must decide as fast as possible whether it is symmetrical or not, **and** how many red blocks there are on a side. Then touch the appropriate space on the screen and wait for the next stimulus figure to appear.

Ready! Press the key indicated as **Begin** to start the trial run.

Rate of Information Processing (Conceptual)
Technical details
There are many similarities between this test and the previous test (RATE OF INFORMATION PROCESSING: PERCEPTUAL). In fact, the sequence of presentation of the stimuli follows a similar pattern.

This test consists of **six series** and each series consists of 30 trials. There are 30 different stimulus figures (predetermined), which must be presented **randomly** within each series, by making use of **random numbers**.

A warning signal (red dot) is given, and the **first** stimulus figure appears **one second** later. The exposure time (tachistoscopic time) of each stimulus figure is **constant** throughout the test, but should be adjustable 0,1 and 0,5 sec. The experimenter must decide beforehand on the exposure time to be used. The time interval **between** the successive stimuli in each series is also **constant**, but must be adjustable from one series to the next. The following times are proposed for the six successive series:

OPTION NUMBER 1

Series	Rate
1.	One stimulus every 3,00 sec
2.	One stimulus every 2,50 sec
3.	One stimulus every 2,14 sec
4.	One stimulus every 1,88 sec
5.	One stimulus every 1,67 sec
6.	One stimulus every 1,50 sec

OPTION NUMBER 2

Series	Rate
1.	One stimulus every 2,00 sec.
2.	One stimulus every 1,67 sec
3.	One stimulus every 1,43 sec
4.	One stimulus every 1,25 sec
5.	One stimulus every 1,11 sec
6.	One stimulus every 1,00 sec

It is important to note that these times **include** both the interval between stimuli and the **tachistoscopic time**.

The research participant must decide whether or not the stimulus figure that is presented meets certain criteria. If it meets the criteria, he/she must touch the space under the stimulus figure marked "Yes" with his/her index finger. If it does not meet the criteria, he/she must touch the space marked "No" with his/her index finger. The spaces marked "Yes" and "No" must be visible throughout.

The research participant's score is the total number of **correct** responses, which must be registered for all trials and series.

Use the first five figures for the practice exercise, but present them **randomly**.

Procedure
All the chronometric measures referred to were administered to the sample of pilots by means of the computerised system. A file was opened for each of the pilots and his/her test data were stored therein. All the necessary statistical computations (e.g. means and variances) were done **instantaneously** by the computer.

It merits mentioning that due to time constraints the number of stimuli (trials) per series had to be reduced from 30 to 10 in respect of both Information Processing Tests (Perceptual and Conceptual).

Statistical analysis
In order to develop an appropriate **scoring system** for each of the tests, the various scores (trials) were intercorrelated, and where necessary, subjected to factor analysis. The number of factors was estimated according to Kaiser's (1961) criterion. **Oblique rotations** (Direct Oblimin) were used throughout.

RESULTS

Test 1: Choice Reaction Time
As a first step the ten subtests of the Choice Reaction Time Test were intercorrelated. The matrix of intercorrelations is given in Table 3.

From an inspection of Table 3 it can be seen that RT1 (zero bits) is essentially uncorrelated with the other subtests of the Choice Reaction Time Test. All the other subtests are statistically significantly positively correlated with one another.

TABLE 3
MATRIX OF INTERCORRELATIONS OF REACTION TIME MEASURES

Reaction Time	RT: 1	RT: 2	RT: 4	RT: 8	RT: 9	RT: 16	RT: 25	RT: 36	RT: 49	RT: 64
RT: 1	1,000	0,021	0,193	0,064	0,122	0,038	0,188	0,215	0,176	0,195
RT: 2	0,021	1,000	**0,540**	**0,480**	**0,559**	**0,453**	**0,348**	**0,435**	**0,291**	**0,435**
RT: 4	0,193	**0,540**	1,000	**0,482**	**0,376**	**0,516**	**0,268**	**0,307**	**0,273**	**0,429**
RT: 8	0,064	**0,480**	**0,482**	1,000	**0,383**	**0,551**	**0,464**	**0,439**	**0,512**	**0,507**
RT: 9	0,122	**0,559**	**0,376**	**0,383**	1,000	**0,517**	**0,490**	**0,555**	**0,400**	**0,467**
RT: 16	0,038	**0,453**	**0,516**	**0,551**	**0,517**	1,000	**0,473**	**0,491**	**0,474**	**0,522**
RT: 25	0,188	**0,348**	**0,268**	**0,464**	**0,490**	**0,473**	1,000	**0,554**	**0,655**	**0,662**
RT: 36	0,215	**0,435**	**0,307**	**0,439**	**0,555**	**0,491**	**0,554**	1,000	**0,488**	**0,587**
RT: 49	0,176	**0,291**	**0,273**	**0,512**	**0,400**	**0,474**	**0,655**	**0,488**	1,000	**0,709**
RT: 64	0,195	**0,435**	**0,429**	**0,507**	**0,467**	**0,522**	**0,662**	**0,587**	**0,709**	1.000

Note: All the values in **bold** are statistically significant: $p < 0,01$

Next, the eigenvalues of the unreduced intercorrelation matrix were calculated. The eigenvalues are given in Table 4.

From an inspection of Table 4 it can be seen that only two of the eigenvalues are greater than unity. Accordingly two factors were postulated (Kaiser, 1961).

Next, two factors were extracted by means of the principal factor technique, and rotated to simple structure by means of a Direct Oblimin rotation. The rotated factor matrix is given in Table 5.

From an inspection of Table 5 it can be seen that RT25, RT36, RT49, and RT64 load on Factor 1, and RT2, RT4, RT8, RT9, and RT16 on Factor 2. RT1 has a very low loading on Factor 1 and shares very little of its variance with the other measures. The two factors correlate 0,589 with one another.

It is suggested that **two scores** be computed for Choice Reaction Time by summing the reaction times in respect of the measures that load substantially on the respective factors.

Test 2: Discrimination Time (Form)
Three scores were taken in respect of the Discrimination Time Test (Form). These scores were intercorrelated and are given in Table 6.

From an inspection of Table 6 it appears that Accuracy is essentially **uncorrelated** with Decision Time and Response Time. However, Decision Time is moderately **negatively** correlated with Response Time ($r = -0,632$). It is therefore justified keeping all three scores when scoring the test.

Table 4
Total variance explained: reaction time test

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**4,862**	48,620	48,620	4,432	44,320	44,320	3,734	37,34	37,34
2	**1,159**	11,593	60,213	0,713	7,129	51,448	3,601	36,01	73,35
3	0,964	9,638	69,851						
4	0,752	7,519	77,369						
5	0,502	5,020	82,389						
6	0,466	4,656	87,045						
7	0,417	4,170	91,215						
8	0,335	3,348	94,563						
9	0,304	3,038	97,601						
10	0,240	2,399	100,000						

Table 5
Rotated factor matrix (direct oblimin)

	Factor		
Variable	1	2	h_j^2
RT: 49	**0,848**	0,040	0,681
RT: 25	**0,788**	0,034	0,654
RT: 64	**0,718**	0,184	0,704
RT: 36	**0,494**	0,291	0,498
RT: 1	0,243	-0,027	0,052*
RT: 2	-0,097	**0,831**	0,604
RT: 4	-0,071	**0,731**	0,478
RT: 16	0,244	**0,560**	0,534
RT: 9	0,240	**0,513**	0,466
RT: 8	0,275	**0,489**	0,473

Factor correlation matrix

Factor	1	2
1	1,000	**0,589**
2	**0,589**	1,000

Note: RT1 has very little in common with the other measures

Table 6
Matrix of intercorrelations of the form discrimination measures

Variable	Accuracy	Decision Time	Response Time
Accuracy	1,000	0,017	-0,034
Decision Time	0,017	1,000	-0,632 **
Response Time	-0,034	-0,632 **	1,000

Note: **Correlation is significant at the 0,01 level (2-tailed)

Test 3: Discrimination Time (Colour)
Three scores were also taken in respect of the Discrimination Time Test (Colour). These scores were intercorrelated and are given in Table 7.

Table 7
Matrix of intercorrelations of the colour discrimination measures

Variable	Accuracy	Decision Time	Response Time
Accuracy	1,000	-0,053	0,126
Decision Time	-0,053	1,000	-0,626 **
Response Time	0,126	-0,626 **	1,000

Note: **Correlation is significant at the 0,01 level (2-tailed)

From an inspection of Table 7 it is clear that the pattern of intercorrelations is very similar to that of the Discrimination Time Test (Form). Again Decision Time is moderately negatively correlated with Response Time (r = –0,626). Keeping all three scores when scoring the test is therefore justified.

Test 4: Rate of Information Processing (Perceptual)
As a first step the various subtests (rates) of the Information Processing Test (Perceptual) were intercorrelated. The matrix of intercorrelations is given in Table 8.

Next, the eigenvalues of the unreduced intercorrelation matrix were calculated. The eigenvalues are given in Table 9.

From an inspection of Table 9 it can be seen that only one of the eigenvalues is greater than unity. Accordingly one factor was postulated and extracted by means of the principal factor technique. The obtained factor matrix is given in Table 10.

From an inspection of Table 10 it can be seen that all the different rates have substantial loadings on the obtained factor. The slowest rate (2 000 milliseconds) has the lowest loading (0,396). It is therefore suggested that a single score be computed for the Information Processing Test (Perceptual). The sum of scores (number right) over all the rates seems the best option here.

Test 5: Rate of Information Processing (Conceptual)
As a first step the various subtests (rates) of the Information Processing Test (Conceptual) were intercorrelated. The matrix of intercorrelations is given in Table 11.

Table 8
Matrix of intercorrelations of the rip-test (perceptual)

Variable	Perceptual Acc/2000	Perceptual Acc/1670	Perceptual Acc/1430	Perceptual Acc/1250	Perceptual Acc/1110	Perceptual Acc/1000
Perceptual\:Acc/2000	1,000	**0,293**	**0,400**	0,168	0,186	**0,259**
Perceptual\:Acc/1670	**0,293**	1,000	**0,408**	**0,292**	**0,328**	**0,309**
Perceptual\:Acc/1430	**0,400**	**0,408**	1,000	**0,583**	**0,465**	**0,447**
Perceptual\:Acc/1250	0,168	**0,292**	**0,583**	1,000	**0,483**	**0,497**
Perceptual\:Acc/1110	0,186	**0,328**	**0,465**	**0,483**	1,000	0,438
Perceptual\:Acc/1000	**0,259**	**0,309**	**0,447**	**0,497**	**0,438**	1,000

Note: Coefficients printed in **bold** are statistically significant (p = 0,01)

Table 9
Total variance explained: rate of information processing test (perceptual)

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**2,899**	48,310	48,310	2,339	38,987	38,987
2	0,942	15,704	64,014			
3	0,698	11,630	75,644			
4	0,566	9,426	85,070			
5	0,544	9,069	94,140			
6	0,352	5,860	100,000			

Table 10
Factor matrix of rate of information processing test (perceptual)

Variables	Factor 1	h_j^2
Perceptual Acc/2000	**0,396**	0,157*
Perceptual Acc/1670	**0,503**	0,253
Perceptual Acc/1430	**0,789**	0,623
Perceptual Acc/1250	**0,704**	0,496
Perceptual Acc/1110	**0,633**	0,401
Perceptual Acc/1000	**0,642**	0,412

Note: *Communality very low

Next, the eigenvalues of the unreduced intercorrelation matrix were calculated. The eigenvalues are given in Table 12.

From an inspection of Table 12 it can be seen that **two** of the eigenvalues are greater than unity. Accordingly two factors were postulated and extracted by means of the principal factor technique. The obtained factor matrix was rotated to simple structure by means of a Direct Oblimin rotation. The rotated factor matrix is given in Table 13.

From an inspection of Table 13 it is clear that the slowest rate (2 000 milliseconds) has a very low communality (0,131). The following rates have moderate to high loadings on Factor 1: Acc/1110, Acc/1670 and Acc/2000. And the following rates have moderate to high loadings on Factor 2: Acc/1000, Acc/1250 and Acc/1430. With the exception of Acc/1110, Factor 1 represents relatively slow rates and Factor 2 relatively fast rates. The two factors are moderately **positively** correlated (r = 0,427).

Table 11
Matrix of intercorrelations of the rate of information processing test (conceptual)

Variable	Conceptual Acc/2000	Conceptual Acc/1670	Conceptual Acc/1430	Conceptual Acc/1250	Conceptual Acc/1110	Conceptual Acc/1000
Conceptual\:Acc/2000	1,000	0,188	0,159	0,095	**0,334**	0,088
Conceptual\:Acc/1670	0,188	1,000	**0,273**	0,185	**0,484**	**0,265**
Conceptual\:Acc/1430	0,159	**0,273**	1,000	**0,273**	0,185	**0,238**
Conceptual\:Acc/1250	0,095	0,185	**0,273**	1,000	0,093	**0,394**
Conceptual\:Acc/1110	**0,334**	**0,484**	0,185	0,093	1,000	**0,325**
Conceptual\:Acc/1000	0,088	**0,265**	**0,238**	**0,394**	**0,325**	1,000

Note: All the coefficients printed in **bold** are statistically significant (p < 0,05)

Table 12
Total variance explained: rate of information processing test (conceptual)

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**2,223**	37,051	37,051	1,680	27,994	27,994	1,502	25,033	25,033
2	**1,129**	18,823	55,874	0,653	10,876	38,870	1,253	20,883	45,916
3	0,842	14,036	69,910						
4	0,782	13,025	82,935						
5	0,594	9,894	92,829						
6	0,430	7,171	100,000						

Table 13
Rotated factor matrix of rate of information processing test (conceptual)

	Factor		
Variable	1	2	h_j^2
Conceptual:Acc/2000	**0,355**	0,015	0,131*
Conceptual:Acc/1670	**0,501**	0,155	0,342
Conceptual:Acc/1430	0,149	**0,353**	0,192
Conceptual:Acc/1250	-0,154	**0,790**	0,543
Conceptual:Acc/1110	**0,931**	-0,110	0,791
Conceptual:Acc/1000	0,175	**0,480**	0,333

Note: Direct Oblimin rotation

Factor correlation matrix

Factor	1	2
1	1,000	**0,427**
2	**0,427**	1,000

It is suggested that two scores be computed for Information Processing (Conceptual) by summing the scores in respect of the measures that load on the respective factors.

The means and standard deviations of the various scores, derived in respect of the foregoing chronometric measures, are given in Table 14.

With the exception of the Accuracy scores of the Discrimination Tests (Shape and Colour) all the measures have a wide dispersion, suggesting acceptable reliabilities.

DISCUSSION

The Choice Reaction Time Test yielded two scores – one representing the measures involving relatively little information (bits), namely RT2, RT 4, RT 8, RT 9 and RT 16, and one representing the measures involving considerable information (RT 25, RT 36, RT 49 and RT 64). RT 1 involves no choice at all (zero bits) and has very little in common with the other measures, as is evident from its low communality (0,052). RT 1 should therefore be excluded from the scoring system.

Table 14
Means and standard deviations of the various chronometric measures

Variable	Mean	Standard Deviation	N
Reaction Time: Factor 1	3677,641	396,057	58
Reaction Time: Factor 2	2988,879	324,396	58
Form Discrimination: Accuracy	96,552	3,849	58
Form Discrimination: Decision Time	899,310	564,018	58
Form Discrimination: Response Time	1052,347	581,254	58
Colour Discrimination: Accuracy	94,650	4,990	58
Colour Discrimination: Decision Time	999,609	595,083	58
Colour Discrimination: Response Time	1224,683	769,090	58
RIP (Perceptual)	503,793	85,118	58
RIP (Conceptual) Factor 1	205,690	44,882	58
RIP (Conceptual) Factor 2	195,690	49,951	58

The two discrimination time tasks (shape and colour) yielded very similar patterns of intercorrelations between the scores. In both cases Accuracy was essentially **uncorrelated** with Decision Time and Response Time, and Decision time was **moderately negatively** correlated with Response Time (r = -0,632 and –0,626 respectively). Keeping all three scores therefore seems justified.

As far as Rate of Information Processing (Perceptual) is concerned, a single factor was obtained. All the different rates yielded substantial loadings on this factor, with the exception of the slowest rate (2000 milliseconds). This is probably due to a **lack of variance** in respect of the slowest rate. A single score for this test seems justified.

The Rate of Information Processing Test (Conceptual) yielded two factors, but the identification of the factors is problematic: Factor 1 has moderate loadings in respect of the relatively **slow rates** (Acc/2000 and Acc/1670), but a very high loading in respect of one of the fastest rates (Acc/1110). This might be due to differential skewness of the various rates. Factor 2 has moderate to high loadings in respect of the fast rates (Acc/1430, Acc/**1250** and Acc/1000).

In a future study the effect of different tachistoscopic times and different time intervals between the successive stimuli, in each

series, will be explored. Particular attention will be paid to the skewness of the various series as this might have an effect on the factor structure of the test.

The results of the study seem quite promising, but further work on a larger **random** sample is necessary. The effect of shortening the Information Processing Tests should also be in vestigated. The test-retest reliabilities of the various measures also need to be estimated as Cronbach's coefficient alpha is not suited to speed tests.

REFERENCES

Barkhuizen, W. (2001). Rate of information processing and reaction time of aircraft pilots and non-pilots. *Unpublished technical report*, Rand Afrikaans University, Johannesburg.

Cattell, J.McK. (1890). Mental tests and measurements. *Mind*, 15, 373-380.

Cohen, D. & Shelley, D. (1982). High IQ as high speed thinking. *New Scientist*, 16 September, 773-775.

Cohn, S.J., Carlson, J.S. & Jensen, A.R. (1985). Speed of information processing in academically gifted youths. *Personality and Individual Differences*, 6(5), 621-629.

Galton, F. (1883). *Inquiries into human faculty and its development*. London: MacMillan.

Hick, W. (1952). On the rate of gain of information. *Quarterly Journal of Experimental Psychology*, 4, 11-26.

Jensen, A.R. & Munro, E. (1979). Reaction time, movement time, and intelligence. *Intelligence*, 3, 121-126.

Jensen, A.R., Schafer, E.W.P. & Crinella, F.M. (1981). Reaction time, evoked brain potentials, and psychometric g in the severely retarded. *Intelligence*, 5, 179-197.

Kaiser, H.F. (1961). A note on Guttman's lower bound for the number of common factors. *British Journal of Statistical Psychology*, 14(1), 1.

Meredith, W. (1964a). Notes on factorial invariance. *Psychometrika*, 29, 177-185.

Meredith, W. (1964b). Rotation to achieve factorial invariance. *Psychometrika*, 29, 187-206.

Raven, J.C. (1947). *Progressive Matrices*. London: H.K. Lewis.

Schepers, J.M. (1970). *Sielkundige meting: Huidige status in Suid-Afrika*. Sielkunde-biblioteek 15. Pretoria: Van Schaik.

Schepers. J.M. (1987). Chronometriese studies. *Tegniese verslag*. Randse Afrikaanse Universiteit, Johannesburg.

Sen, A., Jensen, A,R., Sen, A.K. & Arora, I. (1983). Correlation between reaction time and intelligence in psychometrically similar groups in America and India. *Applied Research in Mental Retardation*, 4, 139-152.

Shaw, I.S. & Schepers, J.M. (1988). The application of personal computers in psychometric testing. *Journal of Industrial Psychology*, 14, 23-27.