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THE APPLICATION OF PERSONAL COMPUTERS IN PSYCHOMETRIC TESTING

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ABSTRACT

Personal computers in psychometric testing represent an efficient, inexpensive, user-friendly, and reliable tool for research and training. They offer a number of substantial advantages for both test subjects and test directors. Personal computer-aided testing programs provide for the instruction of test subjects, the presentation of test patterns, the automatic evaluation of results, automatic data collection and statistical processing. Test results can be saved, compared with standard values, and printed out in various formats. User-friendly programming reduces the test directors' work to a minimum and relieve them from routine tasks. Flexibility and low cost are further advantages.

OPSOMMING

Die gebruik van persoonlike rekenaars vir psigometriese toetse word as doeltreffende, goedkoop, gebruiker-vriendelike en betroubare werktuie vir navorsing en opleiding beskou. Hulle bied 'n aantal belangrike voordele aan vir toetslinge asook toetsleiers. Persoonlike rekenaarondersteunde toetsprogramme behels die voorligting van toetslinge, die vertoning van toetspatrone, die outomatiese evaluering van toetsresultate, outomatiese dataversameling asook statistiese dataverwerking. Toetsresultate kan gestoor, met standaardwaardes vergelyk en in verskeie formate uitgedruk word. Die toetsleier se werkbelading word deur middel van gebruikervriendelike programmering tot 'n minimum verminder en hy word ook van routine take bevry. Verdere voordele soos buigsaamheid en lae koste word ook beklemtoon.

INTRODUCTION

Computer-aided psychometric testing offers many advantages in comparison with the more traditional method of printed tests or questionnaires filled out by test subjects. The main areas of interest where computers can provide superior performance may be summarized as follows:

- User interface
- Test pattern generation
- Fast automatic scoring
- Accurate response timing
- Fast automatic statistical calculations
- Database for test results
- Printed report generation in different formats
- Archiving facilities

Systems used in the past employed either central mini- or mainframe computers with a number of terminals, or alternatively, free-standing intelligent terminals equipped with disk drives (such as, for example, the PLATO system). However, the cost of such systems was very high. In addition, the central minicomputers' highly complex operating system required a resident system manager with specialized training, who was in charge of system generation, system software updating and back-up, data management and other activities usually required in data processing installations. In the case of a central processor breakdown, all terminals were debilitated. Although the free-standing units were more flexible and free of many of the disadvantages mentioned, they were still not easily affordable by small– and medium-sized institutions and laboratories. This situation has changed dramatically with the advent of personal computers.

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PERSONAL COMPUTERS

Personal computers can offer the same features, but at a substantially reduced cost. These computers are free-standing individual workstations, thus a breakdown of one unit will not disable any of the other units. The operating system is considerably less complex. If there are but one or two workstations, the test director or psychologist can easily learn to perform the few system management tasks necessary. Such systems are easily affordable by most research or training institutions. A typical estimate would be R4 000 – R6 000 per workstation, and about R10 000 – R15 000 for application software development, depending upon system requirements and complexity. Test directors do not need any specialized computer knowledge and require but little training in running the system.

APPLICATIONS SOFTWARE

The application software, if written in a structured language such as for example, PASCAL, can be easily maintained and expanded by an experienced programmer; since the language is practically self-documenting, this programmer does not have to be always the same individual.

In particular, the language TurboPASCAL offers the additional advantage of an integrated software development environment at the incredibly low price of less than R200. Version 4.0 of TurboPASCAL offers a wide variety of graphics capabilities, support for a variety of monochrome and colour screens with different resolution (such as EGA, CGA, VGA, Hercules, etc.) as well as full file management features. There is no longer a 64 K limitation in program size and overlays are also not required.

For fast and accurate timing, a powerful assembly language interface, including in-line statements and in-line macros, is also included.

Answer-registering devices (keyboards, lightpens, touch screens etc.) can use well-supported hardware interrupts as well as DOS and BIOS system calls. Include files can be nested 8 levels deep. The integrated program development environment includes a full screen editor for editing, compiling, error finding and correcting.

To protect copyrighted applications programs, a pre-compiled version of the program can be generated for distribution. The manufacture, Borland, Inc. permits the use of such programs without a special license.

In the following, a number of examples will be given to highlight each of the earlier outlined performance factors.

USER INTERFACE

TEST DIRECTOR'S DISPLAY SCREEN

- The low peripheral component cost makes it feasible to equip every workstation with two screens: a monochrome screen for the test director, and a monochrome or colour screen for the test subject. Since each workstation is completely self-contained, it can be easily transported to any required site.
- Each test contains a menu specific to that test which, after startup, is displayed on the test director's screen.
- The test director must enter the test subject's personal data and the date and time of the test. He has a number of menu options as follows:
  - start the specific test, score and record the results;
  - perform statistical calculations (minimum and maximum values, mean, median, mode, variance, standard deviation) on the raw test results;
  - view or print the test subject's personal data, raw test results, norm scores, and statistical data;
  - store the test subject's personal data, raw test results, and statistical data in a disk file;
  - retrieve the test subject's personal data, raw test results, and statistical data from a disk file (with a option to display and print the disk directory prior to selecting the file to be read).
  - select certain options specific to the test used.
- if a serial link exists to a minicomputer or mainframe computer for further data processing or archiving, send to or request files from this remote computer.
- These operations can be carried out in any sequence. They can also be used for off-line data processing such as, for example, the reading, statistical processing, and printing of existing data files of test subjects.
- The test director uses the computer keyboard, located at his own screen, for his own entries.

TEST SUBJECT'S DISPLAY SCREEN

- Instructions directed to the test subject are thoroughly explained by way of messages which appear on the screen, emphasized, highlighted in different text colours, even illustrated graphically. These instructions should preferably be presented in the subject's own home language.
- The same screen is used to present test patterns, which elicit a certain response such as, for example, the selective touching of pattern elements, or the touching of choice fields (yes/no) by means of a light pen. Alternatively, (according to Shaw, 1986) the test subject can use another kind of answer-registering device such as, for example, a specialized simplified keyboard or a touch-screen (at considerably higher cost).
- The computer keyboard is available only to the test director, not to the test subject.
- Using such specialized entry devices, the test subject's writing and verbal abilities have no influence on the test results, whereby additional stress is avoided.
- One or more practice sessions are offered for the test on hand, in order to familiarize the subject with the test as well as the scoring.
- If the instructions were still not completely understood, the test director is always on hand to answer any questions. In the case of several workstations each having its own test director screen, one test director can take care of all the necessary entries on each system in a coordinated manner.

TEST PATTERN GENERATION

- Computers offer great flexibility in generating graphic test patterns of different geometric shapes and of different colours (Shaw, 1986).
- Multiple-choice type numeric and alphabetic tests can be created with varying character sizes and styles.
- Whole test batteries can be quickly generated from pre-stored component tests. New tests can be quickly loaded and started.
- High-resolution monochrome or colour pictures of two- or three-dimensional objects can also be generated and displayed.
- The number of test patterns used in any particular test can be fairly high, depending on main memory size.
- Both textual and graphic patterns can be displayed virtually instantaneously on the test subject's screen. The latter is particularly important whenever the test subject's response is timed from the software-controlled initiation of the pattern display to his actuation of a suitable answer-registering device (light pen, pushbutton, key, etc.).
- Text and graphics can be displayed simultaneously, also in colour.
- Multiple choices can be referenced to well-defined fields on the test subject's screen, which must be touched with a light pen, or selected by an identifier by means of an associated keyboard key.

FAST AUTOMATIC SCORING

- For each test, pre-stored correct responses are compared with the test subject's responses and the resulting discrepancies are stored for reporting purposes (Shaw, 1986).

- The test subject's results are software-locked with his personal data in order to prevent falsification. Special passwords can be used to make the test results accessible only to authorized personnel.
- The test scores can be viewed on the test director's screen or printed immediately after completion of the test.

ACCURATE RESPONSE TIMING

- Response timing is, to a certain extent, dependent upon the answer-registering hardware's own response time. An absolute response time accuracy of about 15-20 milliseconds can be achieved fairly easily (Shaw, 1986).
- A timing resolution of 10 milliseconds can be achieved fairly easily.

FAST AUTOMATIC STATISTICAL CALCULATIONS

After completion of a test and the generation of test results, preprogrammed statistical calculations are carried out quickly. The raw data as well as the reduced data can be displayed on the test director's screen, stored on disk, or printed immediately in the form of a report.

DATABASE FOR TEST RESULTS

The file system described above permits the storage and retrieval of test subjects' files in a simple manner. If, however, there is a requirement for sorting and retrieving files according to some particular parameter, then a more sophisticated database is required. For example, it may be required to retrieve and print the files of all test subjects tested between, say, January 15th and February 4th of 19XX, if their Test Y scores were between 60 and 75 percent, etc. Database program packages are commercially available for personal computers and the test subjects' files must then be stored in a format compatible with the particular package selected. However, the size of the hard disk of those workstations requiring this feature must be much larger than in the case of the simple file management system described. This would also increase the hardware costs.

PRINTED REPORT GENERATION IN DIFFERENT FORMATS

- A different layout format may be used for each test.
- Depending on the printer, multiple copies can be printed.
- For high volume printing, fast heavy-duty parallel printers may be employed, albeit at higher cost.
- A single printer can be shared among several workstations. The cables from each computer are then connected to a distributor box equipped with a manual selector switch, whereby the printer is switched to the particular computer, whose data one wishes to print. Alternately, commercially available spooling software may be used which automatically routes the outputs from multiple sources to the printer. This latter solution may cost about five times as much as the former.

ARCHIVING FACILITIES

The purpose of this feature is to store raw and/or processed data for future research. Data transfer to a mini- or mainframe computer can be made via serial transmission links and a suitable terminal concentrator.

In a low-cost system, however, direct data transmission between every workstation and the larger system is not favoured because of the costs involved. Instead, data should be transferred to the larger system by means of suitable mass storage media such as, for example, floppy disks or magnetic tape. Large-capacity floppy disks (0,7 and 1,4 Megabytes) are suitable, provided that the larger system also has the necessary disk drive to read such disks.

EXAMPLE SYSTEM

The microcomputer-based experimental psychometric test system described here, designed and implemented at the Rand Afrikaans University, Johannesburg, South Africa, satisfies most of the above outlined requirements. It also serves as an example for the application and exposition of the basic principles involved.

The system offers the following tests (Schepers, 1987):

- Choice reaction time;
- Discrimination time (based on the colour of the test patterns presented to the subject);
- Discrimination time (based on the shape of the test patterns presented to the subject);
- Information processing speed (perceptual);
- Information processing speed (conceptual);

In as much as the system is still experimental, norm scores are not yet available. Provisions will be made, however, to accumulate and update the norm scores during data collection.

SYSTEM CONFIGURATION

The system consists of the following hardware and software entities:

- Personal computer, with 640 kbytes of main memory and two 360 kbyte floppy disk drivers.
- Monochrome (amber) display monitor, for system functions and commands executed by the test director.
- Medium-resolution (CGA) colour display monitor, for the presentation of instructions and test patterns to the test subject.
- Multi I/O board with real-time clock and parrallel printer interface.
- Parallel interface ((8255) and counter/timer board for the light pen's detector output.
- Serial printer, capable of printing the test results upon request.
- Infrared emitter/detector unit, mounted in an enclosure along with its own power supply and light pen holder. Its function (see Shaw, 1986) is to sense the presence or absence of the light pen in its holder and notify the computer accordingly.
- Light pen.
- MS-DOS Operating System, Version 2.11.
- TurboPASCAL language and software development environment, Version 3.01.
- Editor program EDLIN or equivalent; Intel 8088 macro-assembler MASM. Linking loader LINK; for the development of assembler language routines.

SYSTEM BLOCK DIAGRAM

The system block diagram is shown in Figure 1.

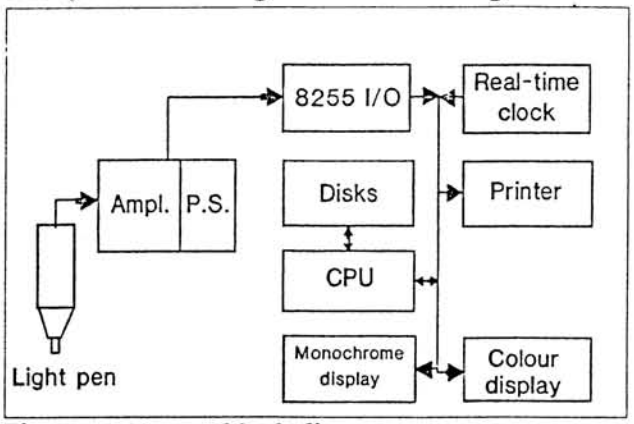

Figure 1. System block diagram

LIGHT PEN SUBSYSTEM

Refer to Figure 2 which illustrates this subsystem. Whenever the light pen is seated in the holder, its switch button interrupts the light beam between the infrared emitter and detector. At this time, the detector output is low. This signal is connected to the computer data bus via one of the input port lines of the 8255 parallel interface board. The program routine related to this interface has a tight waiting loop monitoring low-to-high transitions in the detector output voltage. The detector output delivers standard TTL voltage levels (0...5 volts). The maximum rise time of this signal is one millisecond.

The use of this subsystem will be explained along with the description of tests used.

The fast response and robustness of the light pen has been proven by a long experience with similar systems. It is more readily available, and less expensive, than custom-built keyboards.

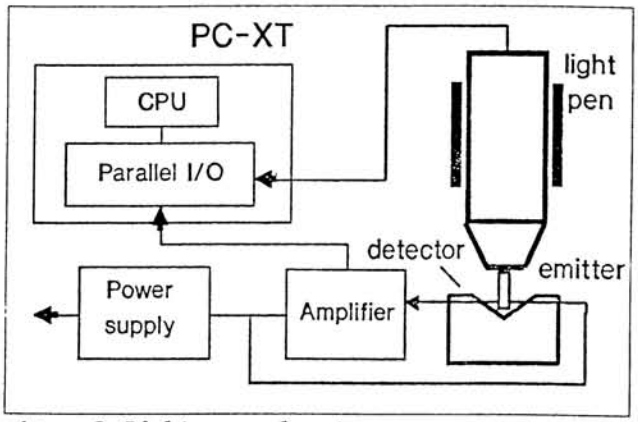

Figure 2. Light pen subsystem

CHOICE REACTION TIME TEST (Adopted from Shaw, 1986)

In this test (according to Schepers, 1987) the subject's capability of reaction to simple visual stimuli rapidly and accurately is measured. Each stimulus series consists of a number of "lamps" simulated by coloured squares on the screen.

The test pattern, consisting of 1, 2, 4, 8, 9, 16, 25, 32, 36, 48 or 64 initially empty squares and covering the entire colour screen, is displayed instantaneously and in a random manner, except that each pattern can occur only once. Shortly after displaying a pattern, a single square is filled with an orange colour. There are 20 different randomly chosen single "lamps", (e.g. filled squares), which are filled in subsequent displays of the same pattern. (The possible repetition of the choice of the same "lamp" is allowed here). The test subject must quickly touch the single filled square with the light pen, then replace it in its holder. The time interval between test patterns is randomly chosen between 0,5 and 2,0 seconds.

Two time intervals are measured and recorded by suitable routines, as follows:

- the time that elapses (after the presentation of the test pattern on the screen) between the filling of a "lamp" and the removal of the light pen from its holder;
- the time that elapses between the removal of the light pen from its holder and the touching of the screen.

If the wrong square is touched by the light pen (instead of that filled with orange), a fault is registered.

If the light pen is removed too soon from the holder, or if it is not removed within a certain time period, or if it is not replaced in the holder in time, an error message is displayed and the particular test is repeated.

The times are measured with an accuracy of + or − 5 per cent. This is achieved in the following manner. The internal system clock is based on interrupts from an Intel 8253 interval/timer/counter. The system timer is Counter 0 of the 8253 which occupies fixed 16-bit I/O port addresses: one for the control register and three for counters O through 2. This counter is initialized at the count of 65536. At a clock rate of 1,19318 Mhz customary with PC's equipped with a 4,77 Mhz crystal oscillator, this means an interrupt rate of about 54,9 milliseconds (or 18,2 Hz). Because of these fractional values, the timer interrupt rate suffers from a certain jitter, which introduces an inaccuracy in the repeatability of timing. As a remedy, the counter is initialized to a much smaller value determined experimentally with a stopwatch. Due to the faster interrupt rate, the timing accuracy and repeatability improves, because the jitter becomes a smaller percentage of the interrupt rate.

Note that the colouring of the "lamp" that is to be "lit up" must be light orange, light green, or light blue, because the light pen requires a certain light intensity to work reliably.

To achieve a practically instantaneous display of a screenful of squares, the patterns are stored in a 512 kbyte RAMdisk. In this test, only 11 patterns must be stored in RAMdisk, because the random colouring of the single square in 20 ways can be achieved programmatically. However, such a large RAMdisk reduces the available memory space rather severely. As a result, a very large percentage of the TurboPASCAL procedures must be stored on disk in include files. (TurboPASCAL Version 4.0 would greatly alleviate this problem).

DISCRIMINATION TIME TEST (BASED ON COLOUR)

In this test, the subject's capability of rapidly and accurately differentiating between colour patterns is measured. Each test pattern displayed instantaneously on the colour screen, consists of three groups of three differently coloured triangles. There are 30 such patterns displayed in a random manner, but every pattern can occur only once. The time interval between successive patterns is chosen randomly between 0,5 and 2,0 seconds. The subject must decide which group does not match the other two in terms of colour and then touch the leftmost triangle of the selected group as quickly as possible with the light pen.

The same time intervals as in the choice reaction time test are measured and registered automatically. If the wrong group has been chosen by the subject, a fault is registered. After each pattern, the subject must replace the light pen in its holder as soon as possible. With regard to light pen manipulation, the same error messages are displayed as indicated above.

The RAMdisk must hold now 30 patterns. This tends to cause difficulties in program compilation, due to the lack of adequate memory space.

DISCRIMINATION TIME TEST (BASED ON SHAPE)

This test is similar to the previous one, except for the test patterns, which consist of three groups of three different geometric shapes (circle, square, triangle) of the same colour. In two of the groups, the sequence of shapes is the same. The test subject must again determine the group whose shapes are in a sequence different from that of the other two. The same times are measured as before. He must quickly touch any of the shapes of the selected group with the light pen, then replace its holder.

Again, there are 30 patterns chosen randomly, to be stored in RAMdisk, and displayed with a random interval of 0,5 to 2,0 seconds.

INFORMATION PROCESSING SPEED (PERCEPTUAL)

In this test, the subject's capabilities of high-speed information processing are measured. Every test pattern presented on the screen contains a vertical yellow column of symmetry and a number of orange blocks on both sides of this column. The test pattern is displayed only for a short time (preselected by the test director's menu between 0,1 and 0,5 seconds), after which the screen is blanked out and two blocks marked 'yes' and 'no' appear. The test subject must determine whether or not the stimulus pattern was symmetrical with respect to the vertical yellow column. He must then touch the respective answer block with the light pen. He is allowed to remove the light pen from its holder prior to the commencement of the test and keep holding it in his hand throughout the entire test.

There are 6 sequences of test patterns, each of which consists of 30 patterns. The preselected "on time" of each pattern remains constant. The time interval between the touching of an answer block and the displaying of the next test pattern remains constant within a sequence, but varies from sequence to sequence in such a manner, that the display rate of successive sequences increases by a set amount. There are two time interval tables stored, each of which contains 6 values (one per sequence). The table is preselected by means of the test director's menu.

Again, 30 test patterns are stored in RAMdisk, chosen and presented at random, but each only once within a sequence. In this case, only the faulty choices of symmetry are recorded, and times are not measured.

INFORMATION PROCESSING SPEED (CONCEPTUAL)

In this test, the subject's capabilities of high-speed information processing are again measured. Each test pattern contains a vertical green column of symmetry as well as a number of orange blocks on both sides of it. The subject must decide whether or not the stimulus pattern is symmetrical, and must also make inferences about the number of orange blocks on each side of the column of symmetry. The test pattern is displayed only for a short time, as before, after which the screen is blanked and the answer blocks are displayed.

If the subject decides, that the test pattern was symmetrical and, at the same time, the number of orange blocks was not less than four and not more than five, then he must touch the 'yes' block, otherwise he must touch the 'no' block with the light pen.

There are 6 sequences of 30 test patterns per sequence. All that was described above with respect to accelerated displays and the time tables applies here as well. The subject is again allowed to hold the light pen permanently in his hand.

SUMMARY

The systems requirements, technical capabilities and economic advantages of personal computers used for psychometric testing were treated in detail. A personal computer system with a light pen interface, designed and built by the authors and applied to psychometric testing, was described.

As a future developmental task, the floppy disks may be replaced with a hard disk of suitable capacity, whereby the system set-up and operation would be greatly simplified.

The feasibility of accurate reaction time timing, reliable multiple choice selection of graphics based on colours and shapes, the automatic evaluation of responses, the generation and instantaneous display of a large number of test patterns, and the printing, storage, retrieval, and statistical evaluation of data has been demonstrated in a cost-effective system using a widely available type of inexpensive personal computer.

The principles used can also be adapted to personal computer-aided training.

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