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AN EXPERT SYSTEM FOR THE SELECTION OF STATISTICAL TESTS

by

MICHAEL HENRY ARTHRELL SMITH

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Supervisor: Dr. R.P. KNOTT

ABSTRACT

A particular area of difficulty was identified in the statistics that A-level psychology students are required to learn. The background to the use of a computer based system in education is discussed. A simple expert system, developed to provide an additional learning resource for the lecturer, is documented. The use of micro-PROLOG and the apes expert system shell on a Research Machines Nimbus microcomputer is reviewed. The structure of, and code for, the system is given.

Declaration

This dissertation is entirely my own work.

Acknowledgements

A number of people have provided support during the development of this system and my thanks go to all of them. In particular, I would like to thank Keith Stevenson for his advice and encouragement.

Special thanks to Marcia.

The system was implemented using the apes™ expert system shell and micro-PROLOG Professional™.

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CONTENTS

Appendix

INTRODUCTION

During conversations with colleagues who teach psychology to A level students, it became apparent that many students find great difficulty with the statistical work involved in analysing the results of their experiments. The first stumbling block was usually the selection of a test appropriate to a particular experiment.

The nature of the experiment and its results determine the test that should be used. Although the rules governing the choice of test are well defined, summaries which are produced to guide the student in his or her choice leave much to be desired.

It was suggested that a computer-based system, given the relevant data, could not only identify the correct test but also provide an explanation of why that test was chosen. Moreover it could be expected that the system would provide background information to help the student to provide the required data. It was hoped that such a system could be flexible enough to be of use to students with different degrees of familiarity with statistics and statistical terminology.

As a result of these discussions a number of different strategies were considered but the most interesting one seemed to the development of an expert system. Jackson (1986) defines an expert system as:

> "a computing system capable of representing and reasoning about some knowledge-rich domain...with a view to solving problems and giving advice"

The use of expert systems in further education is starting to develop, partly as a result of the work being done at Kingston College of Further Education. However, for both the author and the experts who so patiently co-operated with him, it was an exploration of a new aspect of the use of computers.

The pilot version of the program that was produced and is the subject of this report, was designed to be used by individual students working with a minimum of supervision. It was hoped that, once students had gained some familiarity with the system, they would find it a useful tool in their experimental work.

AIMS OF THE PROJECT

It was hoped that this project would result in the provision of a computer based tool for psychology students attempting to select a statistical test appropriate to a given experiment.

The system was designed to :

i) allow students to circumvent, to some degree, the difficulties arising from the need to analyse the results of experiments;
ii) impart some basic knowledge in statistics;
iii) provide an opportunity for students to gain a deeper understanding of the process of test selection;
iv) give students an untraumatic introduction to the use of computers and expert systems.

Before describing how it was hoped to achieve these aims, it would be useful to put them in an educational context. The use of computers in education is still at a very early stage of development but any examination of this area ought to take account of what is likely to happen in the not too distant future. Some of the issues raised in the following discussion may not apply directly to this program but are important to educational computing in general.

On one level this program is seeking to provide, for the student, a tool that he or she may simply use to help overcome the difficult problem of choosing a correct statistical test in a given set of circumstances. This approach would naturally develop towards using the computer's arithmetic capabilities to actually process the students data, a facility that was not introduced into the program. The use of electronic devices to assist in carrying out calculations is well established in education, freeing learners from the drudgery of seemingly endless 'number-crunching'. The use of a system that ascertains the characteristics of the experiment and its results in order to select the appropriate test could be seen as merely an extension of this idea, insulating the student of psychology from the mysterious world of statistics.

From a purely practical point of view it may only be necessary to tell the student which test to use, without attempting to provide an explanation, in order to allow that student to complete the experimental process. However this is objectionable for a number of reasons. Firstly, computer-based decision makers must always be able to justify their decisions. This gives a user the opportunity of rejecting the decision if he or she is unhappy about the way it was derived. The complexity and pseudo-intelligence of a computer must not be used to hide the workings of even good decision-making models, let alone those of dubious quality. In education this is doubly important - not only is a learning opportunity lost but a tendency, for people to treat the output from computers as infallible, is reinforced.

Weizenbaum (1984) exhorts teachers at all levels to help their students to be aware of the huge limitations of computer models of the real world. He fears that the indiscriminate use of computer models in education will lead to a situation where every student,

> "will have been given a certain facility for the creation of computational models without any corresponding knowledge of their limitations....But what is even more worrisome is that the kind of naive simplemindedness I am here talking about, results in, yes is, an abdication of responsibility, a closing of the mind to reality without an accompanying sense of incompleteness".

This failure to distinguish reality from a computer model of reality is a problem that will have to be faced increasingly as the computer programs used in education become more sophisticated.

The decision-making model produced in this project is not hidden and is therefore open to criticism from both student and lecturer, its limitations clear to see. This is one result of its development as an expert system.

A further objection is that the analysis of experimental findings should not be considered in isolation from the design and implementation of the experiment itself. An understanding of the significance and limitations of statistical techniques is considered important. Understanding is not usually enhanced by a device that acts like a black box, details of the experiment being fed in one end and the correct test coming out the other.

It is hoped that the availability of both background information and a justification of the result will help students to understand why certain tests can be used with some kinds of experiment but not with others. However, in this respect the program is very simplistic. When a user requests help, a predetermined screen of information is presented, the nature of the assistance given does not vary from user to user. The facility to explore the knowledge stored in the system is severely limited, this must be one of the main restrictions, in educational terms, of the program.

The development of artificial intelligence techniques in learning brings with it a vision of future educational programs of such flexibility, that each user is dealt with in a manner appropriate to his or her needs, as perceived by the program itself.

OUTLINE OF THE SYSTEM

The author set out to achieve the aims, discussed above, by providing:

- a basic expert system that could hold the knowledge base, select an appropriate test based on interaction with the user and generate a justification of its selection;
- an interface appropriate to the needs of the expected users;
- compatibility in content, language and style with the student's classroom work in statistical methods.

The expert system

Any expert system, however simple, includes a knowledge base and an inference engine.

The knowledge base is an appropriate representation of the facts and rules extracted from the human expert. In this case the circumstances under which particular statistical tests are appropriate.

The inference engine is that part of the system that controls the way in which the facts and the rules are dealt with in order to find solutions to particular problems.

It is possible to construct a simple expert system without very much difficulty using a commercially available inference engine and interface (together known as an expert system shell). One of the major areas of concern in this project was the production of a suitable interface.

The Interface

The interface between the relatively straightforward expert system mechanism and the student attempting to use the computer is of fundamental importance. As in this case, where the users are likely to have had little experience of computers it is important that the interface promotes a sense of confidence in the system.

Sommerville (1986) highlights three aspects of good design that the author has tried to incorporate into his interface.

The interface should be suitable for the needs and abilities of individual users rather than be simply in a form that is convenient for the designer to implement. This was achieved by hiding as much of the expert system mechanism as possible and avoiding the use of computer terminology. Control of the system was kept simple.

The interface should be consistent. The requirement of consistency is one that can be met through a structured approach to programming and self discipline on the part of the system implementer.

The interface should provide comprehensive 'help' facilities. This is particularly important in an educational environment where the distinction, between the learning involved in solving the problem with which the system is helping and the learning involved in using the system itself can become rather meaningless.

Many of the observations and suggestions made by Bajpai (1985) about the development of software for Mathematics Education were also considered relevant to this project.

There are a number of ways in which the user can control the functioning of a system. A menu-driven interface was chosen as it seemed to be the most appropriate in this particular situation. The flexibility allowed by a command language simply isn't needed as the system itself will only function in an inflexible manner.

Using menus for ALL the interaction with the user eliminated the need for him or her to learn any commands before starting. Obviously the user would have to learn how to select an item from the menu, but having acquired that ability all the functions of the system would become available when appropriate.

The menu system leads the user through the interaction necessary to solve the problem under consideration. The user may feel that he/she has got little control over what is happening. In many circumstances this may have a detrimental effect but in this particular case it should be an advantage since the novice user is more likely to feel reassured than threatened or held back by the system.

Another great advantage of using menus throughout is that the user input is predefined and the problems of validation are avoided. For the user, the frustration of errors caused by wrong spelling or incorrect syntax are completely eliminated.

The other major area of concern was the style and content of both the 'help screens' and the dialogue between the user and the computer. It was thought that for the system to be 'friendly' it was not sufficient for the interface to be simple to use. In addition the student ought to find familiar points of reference. For instance, in explaining how to sort out how many variables existed in a given experimental procedure an example is provided. This example is commonly used by the lecturers themselves when covering this particular subject in class.

The terminology used in the dialogue and the background material is that employed by the lecturers whose students will use the system. This ought to provide the user with some reassurance; many of the words or phrases will have been heard or seen before, in a similar context.

Whilst this approach will, hopefully, make the system easier to use initially, there is a danger that in covering the same material in the same way as the lecturer, some opportunities for developing the student's understanding will have been lost. In an attempt to reduce this danger, the background information provided on 'help screens' has mentioned, where appropriate, alternative terminology. In the effort to shape the computer-based system to match the style and content of one particular course it may be that it has lost some of its universal appeal. Whether or not this is a serious problem remains to be seen.

The knowledge contained within the system must, of course, be correct. Fortunately, in statistics at this level, there seems to be little dispute as to what is correct. Great care was taken to avoid any ambiguity in the statements made and, overall, the author is confident that the validity of the statistics content is beyond reasonable question within the context of psychology teaching at this college.

USE OF "apes"

Rather than attempting to develop all of the mechanism required for this system it was decided to use an expert system shell, "apes" - Augmented Prolog for Expert Systems. Although the choice was largely governed by the fact that the package was already available at the college, it was recognised that the use of "apes" would allow a great deal of flexibility during the development of the system.

"apes" is a collection of over thirty modules written in PROLOG that provides many of the features normally associated with expert systems - most importantly, a front-end and an interpreter that generates proofs of all its conclusions.

The "apes" 'standard front-end' is a configuration of these modules that provides facilities for creating and editing knowledge bases and executing queries. This standard configuration is extremely useful for the development of an expert system but is not necessarily appropriate for the eventual user of the system. Many of the facilities would not be required by a student using the statistics system, and it was considered that their availability would be a potential source of confusion.

Whilst it is possible to adapt the standard front-end it was decided that a different configuration was required. This was implemented in PROLOG using "apes" modules to provide all of the standard expert system facilities.

Sixteen of the "apes" modules were used:-

Name	Function
error	error handler
utility	a collection of simple utilities used by other modules
parser	enables translation from sentence syntax to standard syntax
interact	controls some of the interaction with the user
frontint	controls the remainder of the interaction
menu	controls all input via menus
tt	controls all keyboard input
escape	enables exit from interaction
query	enables queries about knowledge base to be investigated
exec	"apes" interpreter
exit	enables user to leave the system
how	explains how a conclusion has been confirmed
hownot	explains why a particular conclusion could not be confirmed
mvars	handles meaningful names
browse	allows user to manipulate text files
expand	enables help text to be used

Most of the modules were used in their original form. However, in order to construct the simple interface that was required, a few of them had to be altered slightly. For example,

> the 'query' module was designed so that when a query is invoked the user is asked to choose between four types of query:
>
> 'interaction with-explanation';
> 'interaction without-explanation';
> 'no-interaction with-explanation';
> 'no-interaction without-explanation'.
>
> Only the first of these was appropriate for the statistics system and it was thought that requiring the user to make the choice was detrimental to the interface. The module was altered so as to bypass this particular bit of interaction.

Observations on the use of "apes"

As mentioned above, the use of an expert system shell avoids the need to program the required facilities. The main drawback with many shells is that the interface may not be appropriate to the requirements of a particular situation but cannot be fundamentally altered. The developer of a system will have little control over the style of the interaction as this is determined by the way in which the facilities have been implemented in the shell.

The modular construction of "apes" enabled the production of an interface that was designed to meet the needs of a particular group of users. The documentation that accompanied "apes" gave details of each module and identified ways in which they could be tailored to suit different circumstances. Unfortunately there were some details of a number of modules that were considered undesirable for this system, alterations were made by studying the construction of the module and then making the necessary changes. This was only possible due to the fact that "apes" is implemented in PROLOG. Changes made in this way were extremely time-consuming and on reflection may not have justified the amount of energy expended.

For example:-

> One of the 'HELP' options in the final system invokes a PASCAL program that, among other things, draws a normal curve on the screen. On returning from this routine the original screen display is corrupt, to restore the display it is necessary to enter 'CONTROL-R' from the keyboard.
>
> In order to remove the responsibility of doing this, from the user, it was thought that it would be a simple matter to get the program to do it automatically. This turned out not to be the case, and it was only after days of work that a solution was eventually found.

The main problem with making these alterations was that the construction of individual modules was largely undocumented. As indicated above, some aspects of a modules behaviour were intended to be flexible and were thus implemented and documented in an appropriate manner. The major part of each module, however, was undocumented and implemented in terse,dense PROLOG code. It was never intended that a user of "apes" would tamper with the internal workings of the modules.

When so much control over the style of the implementation is required, the use of an expert system shell may well be inappropriate. In this case, even "apes" did not provide enough flexibility. As in most development situations a balance between what one would like to produce (in order to meet the perceived needs of the users) and what one is able to produce (given the constraints of time etc.) has to be achieved. It seems, in the light of the experience gained on this project, that this balance is very difficult to attain.

In the situation where flexibility is required, "apes" could be used to help produce a prototype system in a reasonably short time. The importance of producing a prototype was highlighted during this project by the fact that once lecturers had actually used the program, their ideas about the nature of the system changed. No doubt, after a period of classroom testing these ideas will change further.

USER DOCUMENTATION

The User Documentation is in two parts, A Student's Guide and A Lecturer's Guide.

It was intended from the outset that the final system should require the minimum of external user documentation. An attempt was made to incorporate help facilities within the system itself - the extent to which this has been successful can only be assessed after full scale testing with students.

As the system was designed to fit in with a teaching program it is quite likely that its use would be demonstrated by the lecturer at some point. It is possible that the step by step explanation, contained in the lecturer's guide, might be repeated in a student learning pack together with other learning materials related to the use of this system. It was thought unwise to produce such material before pilot testing as the system is likely to change in the light of those results.

The lecturer's guide is rather more detailed than that provided for the student and gives a step by step account of how to use the system.

As suggested above, the documentation itself will be developed as necessary, during and following pilot testing.

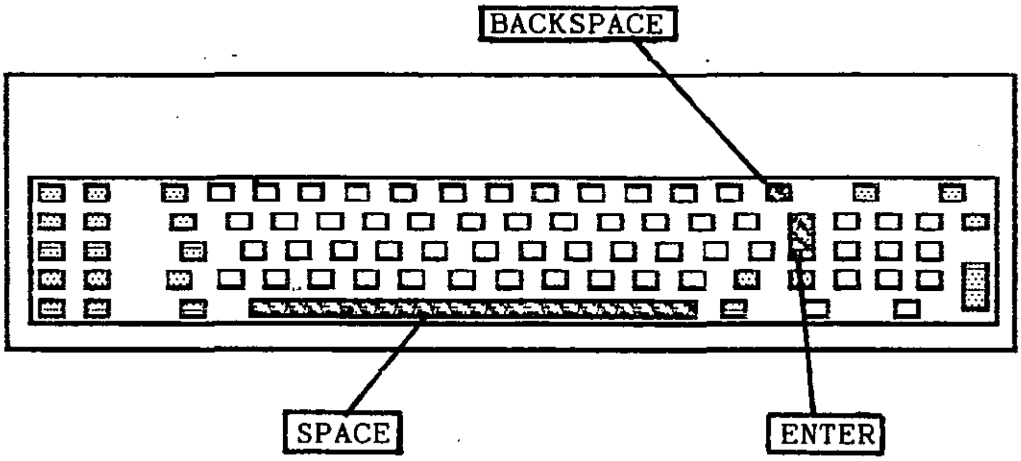
STATISTICAL TESTS EXPERT

A Student's Guide

This system should help you to learn something about making the correct choice of statistical test for the results of your experiments.

Hopefully you should get the hang of using the computer quite quickly. You only need to use three of the keys on the keyboard : BACKSPACE, ENTER and SPACE.

The location of each key is shown below:-



All the information you need about how to use the system should be available from the computer. Use the HELP facilities.

STATISTICAL TESTS EXPERT

A Lecturer's Guide

COMPUTER -	RM Nimbus PC with a disc drive
DISC	Statistical Tests Expert

This computer program is a simple example of what is known as an "Expert System". The computer program contains information about a number of statistical tests, this information relates to the circumstances in which it is appropriate to use each test. (Help with the actual carrying out of the tests is not yet available)

The person using the system is asked to supply various items of information about the nature of the experiment that has been carried out. Using this information the system will determine which test, if any, would be appropriate. The system can be asked to justify its decision and will do so by showing the rules that it used, relating these to the information supplied earlier.

The tests dealt with are:-
Student t ; Mann-Whitney U ; Wilcoxon T ; Chi-squared ; Pearson's correlation r ; Spearman's correlation rho ; 1- and 2-way ANOVA ; Kruskal-Wallis ; Page's L Trend and Friedman.

This guide will show you how to get started and give you a brief step by step account of its use.

Getting Started

1. Switch on computer

2. Put disc in disc drive (either drive - if you have two)

The computer will now spend two or three minutes loading the program . During this time various items of information will appear on the screen, read these as they should be helpful.

3. Eventually the computer will display some important information about how to use the MENU system. (A MENU is a list of possible choices, the user has to select the appropriate one).

To get started - select the "get started" option from the menu.

4. You should now see the main menu. This allows you four choices

a) HELP

This provides some background information and will be extended as the requirements become clearer.

b) FIND A SUITABLE TEST

Asks questions about the experiment and selects a suitable test.

c) CHECK USE OF A TEST

Asks for a particular test to be chosen from the list, asks questions about the experiment and states if test is suitable or not.

d) FINISH

Allows user to finish using the program.

5. Choose HELP and have a look at the information displayed. You can move from one part to another by using the menus.

6. Get back to the MAIN MENU and think of a simple experiment.

7. Select "Find a suitable test"

8. You are asked a question about the experiment. You should select one of the answers from the menu.

If you are not sure about either the question or the correct response select the HELP option from the menu. This will display some helpful information.

When you have read this, select "stop" from the menu to return to the question. If the help material takes up more than a single screen a "2" will appear in the menu - this allows you to see the second screen.

9. Continue answering the questions.

10. Having got an answer from the system you can then choose either:

STOP - to enable you to go back to the main menu

or HOW - to get an explanation of how the system's decision was arrived at.

11. If you select HOW, the rule that the system used to make its decision is displayed.

You can investigate further by selecting one of the numbered terms in the rule to see how that was satisfied. This can continue until the system indicates that you supplied a particular fact, at which point you can either stop or go back step by step.

The CHECK USE OF A TEST option works in a similar way except that you are required to select one of the available tests before answering the questions.

You can leave the program by using the FINISH option.

TESTING

It was not possible to carry out the sort of pilot testing that would be needed to enable further development of the system before the deadline for submission of this report. It was planned to use the system with the students for which it was intended but changes in lecturing staff made this impossible. The system was designed to fit in with the psychology teaching programme at the college; when this was rearranged, the first opportunity for the use of the system was put back eight weeks, just enough to prevent presentation of the results here.

Naturally, testing was carried out regularly during the development of the system. In addition, one of the psychology lecturing staff has had the opportunity to use the system and assess its usefulness. His comments follow.

Choosing Statistical Tests With The Help Of An Expert System

An evaluation of the system by a user.

Preamble

In 13 years of teaching the subject I have yet to find a satisfying method of helping Psychology students come to grips with the rules that govern the process of choosing the correct type of statistical test for the data they have collected. I would hazard a fairly substantial bet that most teachers in the area of hypothesis testing would agree that students most commonly complain that they can cope with the the mathematical mechanics of a test by following a worked example from one of the text books but what they find most problematical is knowing which test to apply and under what circumstances. Consequently anything that might help students in this area would be welcomed with open arms.

A major stumbling block for communicating information in this area is the specialised meanings that have arisen. For example "Related Samples" is a term that is used in this Expert System to indicate that the two samples are either matched in ability prior to the experimental treatment or indeed are the same sample used once in a treatment with the Independent Variable and then used again in a treatment without. This selfsame process is described as "using correlated samples" or "adopting a within subjects design" or even "employing a matched subjects design" in the various texts on statistical testing that are available to the student. Therefore there is a problem of common language that is often underestimated by teachers and authors and I would hope that any expert system would by dint of its help screens, allow for the language of the "expert" to be quickly understood.

To evaluate this Expert System I have considered four main areas.

1. Does it work from a teachers standpoint?

2. How would students take to it?

3. How useful would it be as a teaching aid?

4. What improvements could be incorporated to make it better.

1. As stated in the Preamble anything that might help to get the student to actively interact with the material on statistical testing is to be welcomed. As the system stands at present it definitely would be an excellent support to a teacher of statistical hypothesis testing. The reason I say that it would be a support is that as it stands at present it would need a teacher to first teach the principles of test choice (closely aligned to the rules governing the expert system) and then the expert system could be introduced as an interactive testing ground of the principles that have been taught. The fact that the system allows for the gradual arrival at an appropriate choice of test is certainly helpful in building up confidence in the student particularly the helpful information that can be accessed from the help screens. However the other major feature to this system is the checking facility such that the reasoning behind a hunch that a test is correct can be tested against the expert. This I can see as being a really useful function for helping students to appreciate that they can become the expert themselves simply by applying the rules as displayed by the expert system. This is a truly educational function too in the sense that this system allows for more advanced learners to test their hunches. With not very much use the student should begin to anticipate the rules and therefore develop his/her own expertise.

2. I feel that students will see this system as the answer to their most pressing problem. They may find however that the mechanics of finding the answer a bit confusing to begin with. It is clear that as stated above this system would be most useful as an aid to the teacher. Students once they have the been given an overall picture of the decision making process necessary for appropriate statistical test choice would be in a better position to empathise with the sorts of questions the system has been programmed to ask. The essential rules are certainly available for inspection under the "how" function but I feel that the reasoning could be better presented. Obviously the major benefactor of this system would be a student well versed in the vocabulary of statistical testing who wants to check his/her hunch against the expert. That student can either take the route of answering the questions that allow the system to deduce an appropriate test from the answers given, or s/he can check the test s/he has chosen against a set of questions appropriate for that test. In either case it would be a most useful tool for any student who wants the security of knowing that s/he has made the right choice.

3. As a teaching aid I can see it being usefully employed to illustrate the process an expert would follow. It is not a stand alone system. It is a system that once the teacher has familiarised him/herself, could be incorporated into the lecturing programme to demonstrate the exact decision making process that has to be follwed for correct selection of the appropriate test. The use as a stand alone expert system would follow after the students had experienced the way the software works.

4. Improvements are possible on any system however there are one or two that I feel could be important to the success of this system. Firstly the titling and intro to the system could be more cheerful and perhaps less clinical. Students will want reassurance that this is not an easy path and although there will be terms that are confusing the help screens are always there and if they persevere the system will help them learn. the Help screens are an essential part of this system and need looking at more closely to make sure they do answer the question unambiguously. There are (and perhaps always will be) difficulties in this area. There is limited space per screen and the interest of the reader has to be maintained. I would recommend that the help screens be given as many vivid examples as possible to make the task of finding out interesting, humourous and informative. Further examples of correlation could be presented for instance, that are either more pertinent to the area of social science than cars and their average speed and fuel consumption or that are more readily identifiable with students' experiences.

NB At time of writing the help screen for homogeneity of variance fails to produce any explanation however by asking for help it still processes your query as yes and leads to a parametric solution. Given the robust nature of parametric tests to a violation of this criterion it is quite a clever response by the machine.

Secondly I feel that for use as a teaching aid the "how" function needs to be thought about a bit more. I realise that microprolog uses the "I can show that" to prove its deduction however for teaching purposes the third person is more acceptable. In other words where the system is saying "I am the Expert and I can prove this because you told me that that and that....", for the student the teacher would perhaps prefer an explanation that was couched more in terms of mapping known information against the criteria for the test.

Thirdly I wonder whether a listing of the responses could appear cumulatively as the program progresses. For example as say the fourth question is being asked could the position on the previous three questions be visible to the student helping him/her to appreciate the gathering of the relevant facts. Something like ;

Differences.....Yes
Variables.......1
Conditions......2

Is your data parametric?

might, if it could be incorporated, help the student see what the expert is driving at and why different answers produce different test choices.

Conclusion

The system works. It would be a boon to all teachers of statistical testing and would be usefully employed by them as an aid to the teaching of the subject area. The system will be seen by students as the answer to their most insurmountable problem. It is stressed that they will need a gradual introduction into the purpose of the questionning but will find the system an invaluable tool once they are reasonably confident of the languge used. There are three improvements offered. With these improvements particularly a review of the Help screen text and attention to the user friendliness of the questionning and the computer's answers then this system could at last be the answer to that perennial student question, "But how do you know which test to use under the circumstances?". If I had this system in my College my answer would be, "Don't ask me.....ask the expert!"

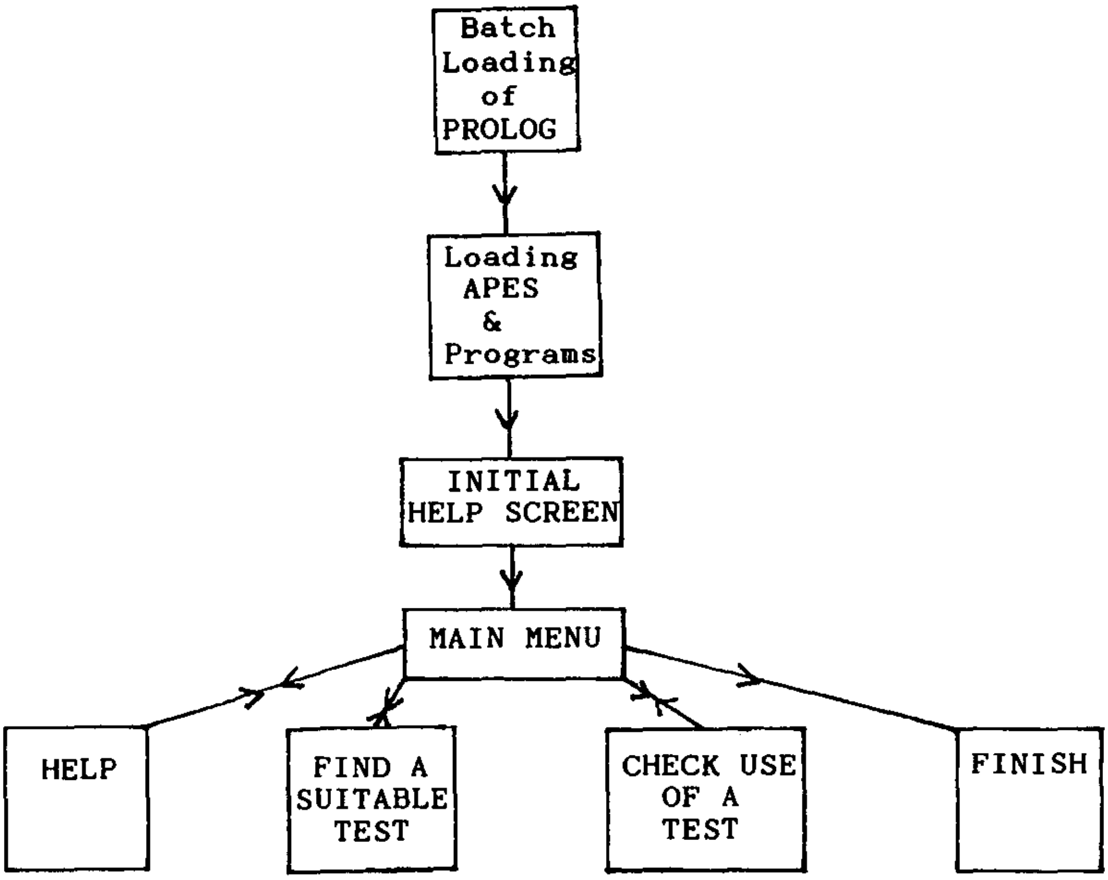
KEITH STEVENSON
Head of Social Sciences
Melton College
Leics
10.1.87

This evaluation of the system, as it is at the present, identifies a number of areas in which modifications could take place. Keith Stevenson has had some experience of using computers and can not be considered a novice user, thus he is in a difficult position to evaluate the interface in respect of its suitability for inexperienced student users. However, he does make some valuable observations about the interface that indicate a need for development.

Note

The missing HELP screen has been found and appears, on request, in the current version.

OUTLINE OF PROGRAM STRUCTURE



Description of the program

A BATCH file is used to initiate the sequence of events that need to take place before the program can be run. This means that only a single command needs to be entered by the user.

The LOADING phase takes quite a long time as each of the required APES modules has to be read in and constructed before the knowledge base and interface details can be input. Some brief items of information are presented,to the user, on the screen during this time.

One of the last things to load is a supervisor program that replaces the normal PROLOG supervisor. This means that if for any reason the program 'crashes' the supervisor program initiates a reset and the program begins again.

The MAIN MENU offers a choice of four actions. After any one of the actions has been completed (with the exception of leaving the program) the program returns to this menu.

The FIND A SUITABLE TEST option gives the user the opportunity to find out which test would be appropriate for a particular experiment. The information required to make a decision is requested by the computer and supplied in the form of answers to a number of questions. The allowed answers are supplied together with an opportunity for the user to obtain some help.

The CHECK USE OF A TEST option asks the user to select one of a number of tests. Through a dialogue with the user, which is in the same form as the previous one, the computer either confirms or fails to confirm the use of that test.

The FINISH option allows the user to leave the program, after the selection of this option the user is asked to confirm that he or she really does wish to finish.

TECHNICAL NOTES

Computer	RM Nimbus PC
Programming Language -	LPA micro-PROLOG professional
Expert System Shell -	Logic Based Systems apes 2.0

The program was written in standard syntax, which is similar to the list syntax of LISP.

The apes modules were designed to be used in a very flexible way and for the most part were included in their original form. However a number of minor alterations had to be made in order to produce the type of behaviour required of the shell, in particular circumstances. These modifications have not been documented here.

PLEASE NOTE

The version provided, on disc, for assessment has been configured to run on a standard RM Nimbus PC. The pilot version at college utilises silicon disc in order to speed up the presentation of help screens.

See APPENDIX A for details of assessment version.

```
/* (Statistics Expert System)
/* (   Load procedure       )

/* (  (C) MHA SMITH , 1987  )

/* (All the programs must be on the default drive)
/* ()
?((P"~L")
  (P"~[")
  (CRWIND base1 0 0 23 78 36 32)
  (CRWIND base2 1 4 21 70 36 0)
  (P"~]")
  (CURSOR base2 6 18)
  (P "~B")(P THE CHOICE OF STATISTICAL TESTS FOR)
  (CURSOR base2 8 26) (P EXPERIMENTAL RESULTS) (P "~D")
  (CURSOR base2 13 24) (P (C) "M.H.A. SMITH" , 1987)
  (CURSOR base2 18 22) (P (APES modules copyright LPA))
  (LOAD "error.ape") (CURSOR base2 17 65) (P 1)
  (LOAD "utility.ape") (CURSOR base2 17 65) (P 2)
  (LOAD "parser.ape") (CURSOR base2 17 65) (P 3)
  (LOAD "interact.ape") (CURSOR base2 17 65) (P 4)
  (LOAD "frontint.ape") (CURSOR base2 17 65) (P 5)
  (LOAD "menu.ape") (CURSOR base2 17 65) (P 6)
  (P "~L") (CURSOR base2 4 8)
  (PP This program has been developed :)
  (CURSOR base2 7 5)
  (P  to enable you to find the correct statistical test)
  (CURSOR base2 8 8)
  (P to apply to the results of your experiments;)
  (CURSOR base2 10 5)
  (P  to allow you to learn about how one decides which)
  (CURSOR base2 11 8)
  (P test to use;)
  (CURSOR base2 13 5)
  (P  to give you the opportunity of using a simple)
  (CURSOR base2 14 8)
  (P 'Expert System'.)
  (CURSOR base2 17 25)
  (P Please wait for the program to load ...)
  (LOAD "tt.ape") (CURSOR base2 17 65) (P 7)
  (LOAD "escape.ape") (CURSOR base2 17 65) (P 8)
  (LOAD "query.ape") (CURSOR base2 17 65) (P 9)
  (LOAD "exec.ape") (CURSOR base2 17 65) (P 10)
  (LOAD "exit.ape") (CURSOR base2 17 65) (P 11)
  (LOAD "how.ape") (CURSOR base2 17 65) (P 12)
  (CURSOR base2 19 35)
  (P Not much longer now !)
  (LOAD "mvars.ape") (CURSOR base2 17 65) (P 13)
  (LOAD "hownot.ape") (CURSOR base2 17 65) (P 14)
  (LOAD "browse.ape") (CURSOR base2 17 65) (P 15)
  (LOAD "expand.ape") (CURSOR base2 17 65) (P 16)
  (P "~L") (CURSOR base2 8 15)
  (P If you have problems with this program ...)
  (CURSOR base2 9 20) (P  ask your lecturer - or a
colleague!)
```

```
  (CURSOR base2 13 15) (P "~B" If you have not used this
program before)
  (CURSOR base2 14 20) (P make use of the help facilities
"~D")
  (LOAD stpx1)
  (LOAD stpx2)
  (LOAD stpx3)
  (CRWIND base 0 0 3 78 144 1)
  (CURSOR base 1 15)
  (P "~B" Statistical Test Selection "~D")
  (CLOSE base1)
  (CLOSE base2)
  (LOAD sumthin))
```

```
/* (Statistics Expert System)
/* (     Part 1             )

/* ( (C) MHA SMITH , 1987    )

/* (The correct circumstances for the use of the various
tests)

((uses-test "1-way ANOVA (related)")
 (data-type differences)
 (number-vars one)
 (number-cons "more than two")
 (OR((subjects same))
    ((subjects different)(samples matched)))
 (data parametric))

((uses-test "Friedman")
 (data-type differences)
 (number-vars one)
 (number-cons "more than two")
 (OR((subjects same))
    ((subjects different)(samples matched)))
 (data non-parametric))

((uses-test "Page's L Trend")
 (data-type differences)
 (number-vars one)
 (number-cons "more than two")
 (OR((subjects same))
    ((subjects different)(samples matched)))
 (data non-parametric))

((uses-test "Kruskal-Wallis")
 (data-type differences)
 (number-vars one)
 (number-cons "more than two")
 (subjects different)
 (samples unmatched)
 (data non-parametric))

((uses-test "1-way ANOVA (unrelated)")
 (data-type differences)
 (number-vars one)
 (number-cons "more than two")
 (subjects different)
 (samples unmatched)
 (data parametric))

((uses-test "2-way ANOVA (unrelated)")
 (data-type differences)
 (number-vars "two or more")
 (subjects different))
```

```
((uses-test "2-way ANOVA (related)")
 (data-type differences)
 (number-vars "two or more")
 (subjects same))

((uses-test "Student t (unrelated)")
 (data-type differences)
 (number-vars one)
 (number-cons two)
 (subjects different)
 (samples unmatched)
 (data parametric))

((uses-test "Student t (related)")
 (data-type differences)
 (number-vars one)
 (number-cons two)
 (OR((subjects same))
    ((subjects different)(samples matched)))
 (data parametric))

((uses-test "Mann-Whitney U")
 (data-type differences)
 (number-vars one)
 (number-cons two)
 (subjects different)
 (samples unmatched)
 (data non-parametric))

((uses-test "Wilcoxon T")
 (data-type differences)
 (number-vars one)
 (number-cons two)
 (OR((subjects same))
    ((subjects different)(samples matched)))
 (data non-parametric))

((uses-test "Spearman's correlation rho")
 (data-type correlations)
 (data non-parametric))

((uses-test "Pearson's correlation r")
 (data-type correlations)
 (data parametric))

((uses-test "Chi-squared")
 (data-type categories))


/* (relating circumstances to user input)
/* (type of experimental data)
((data-type differences)
 (answered dtype1 yes))
((data-type correlations)
 (answered dtype1 no)
 (answered dtype2 yes))
((data-type categories)
 (answered dtype1 no)
 (answered dtype2 no)
 (answered dtype3 yes))

/* (number of conditions)
((number-cons two)
 (answered ncons not-sure)
 (cons two))
((number-cons "more than two")
 (answered ncons not-sure)
 (cons "more than two"))
((number-cons two)
 (answered ncons two))
((number-cons "more than two")
 (answered ncons "more than two"))
/* (more detail if user wasn't sure)
((cons two)
 (answered c1 yes))
((cons "more than two")
 (answered c1 no)
 (answered c2 yes))
((cons "more than two")
 (answered c1 no)
 (answered c2 no)
 (answered c3 yes))

/* (number of variables)
((number-vars one)
 (answered vars one))
((number-vars "two or more")
 (answered vars "two or more"))

/* (nature of the data)
((data parametric)
 (answered dt not-sure)
 (data2 parametric))
((data non-parametric)
 (answered dt not-sure)
 (NOT data2 parametric))
((data parametric)
 (answered dt parametric))
((data non-parametric)
 (answered dt non-parametric))
/* (more detail if user wasn't sure)
((data2 parametric)
 (answered dk "interval or ratio")
 (answered dd "normal or near-normal")
 (answered dv homogeneous))
```

```
/* (type of experimental design)
((subjects same)
 (answered subs same))
((subjects different)
 (answered subs different))
((samples matched)
 (answered samp matched))
((samples unmatched)
 (answered samp unmatched))

/* (natural language templates for explanations)

((read-as uses-test (_t)(use the _t test¦_z)_z))
((read-as data-type (_dt)(the type of data suggests _dt
¦_z)_z))
((read-as number-cons (_nc) (there are _nc
conditions¦_z)_z))
((read-as number-vars (_ev)(the number of variables is
_ev¦_z)_z))
((read-as subjects (_sa)( _sa subjects are used¦_z)_z))
((read-as data (_da)(the experimental data is _da¦_z)_z))
((read-as samples (_sa)(the samples are _sa¦_z)_z))
((read-as data2 (_d2)(your answers indicated _d2
data¦_z)_z))
((read-as cons (_c)(your answers indicated that you had _c
conditions¦_z)_z))

/* (dictionary definitions)

((dict uses-test))
((dict data-type))
((dict number-cons))
((dict cons))
((dict number-vars))
((dict subjects))
((dict data))
((dict data2))
((dict samples))
((dict answered))
```

```
/* (Statistics Expert System)
/* (        Part 2          )

/* (  {C} MHA SMITH , 1987  )

/* (connecting rules to user input)
((answered _rel _res)
 (find _rel _ans)
 ("help?" _rel _ans _res))

/* (menus for user input)
/* ()
((in-menu find (dtype1 _r) (_r) ((yes no  HELP) "data type "
12 30 3 10)))
((in-menu find (dtype2 _r) (_r) ((yes no  HELP) "data type "
12 30 3 10)))
((in-menu find (dtype3 _r) (_r) ((yes no  HELP) "data type "
12 30 3 10)))
((in-menu find (ncons _r) (_r) ((not-sure two "more than
two" HELP) " conditions " 12 30 4 15)))
((in-menu find (c1 _r) (_r) ((yes no HELP) "conditions" 12
30 3 10)))
((in-menu find (c2 _r) (_r) ((yes no HELP) "conditions" 12
30 3 10)))
((in-menu find (c3 _r) (_r) ((yes no HELP) "conditions" 12
30 3 10)))
((in-menu find (vars _r) (_r) ((one "two or more" HELP) "
variables " 12 30 3 15)))
((in-menu find (subs _r) (_r) ((same different HELP) "
subjects " 12 30 3 15)))
((in-menu find (dt _r) (_r) ((parametric non-parametric not-
sure) " data " 12 30 3 17)))
((in-menu find (dk _r) (_r) (("interval or ratio" other
HELP) " ? " 12 30 3 20)))
((in-menu find (dd _r) (_r) (("normal or near-normal" "not
normal" HELP) " ? " 12 30 3 22)))
((in-menu find (dv _r) (_r) ((homogeneous "not homogeneous"
HELP) " ? " 12 30 3 18)))
((in-menu find (samp _r) (_r) ((matched unmatched HELP) "
sample " 12 30 3 12)))

/* (questions for user input)
/*()
((which-template find (dtype1 _r) (_r) (Did you measure the
performance of the subjects in order to"~M~J~I" compare
average performance ?)))
((which-template find (dtype2 _r) (_r) (Were you looking for
a correlation between two variables ?)))
((which-template find (dtype3 _r) (_r) (Did you collect your
data by counting individual occurrences "~M~J~I"into
categories ?)))
((which-template find (ncons _r) (_r) (How many conditions
in your experiment ?)))
((which-template find (c1 _r) (_r) (Did you have a single
experimental condition and a control condition ?)))
```

```
((which-template find (c2 _r) (_r) (Did you have two or more
experimental conditions and "~M~J~I"a control condition ?)))
((which-template find (c3 _r) (_r) (Did you have two or more
experimental conditions and "~M~J~I"more than one control
condition ?)))
((which-template find (vars _r) (_r) (How many variables did
your experiment use ?)))
((which-template find (subs _r) (_r) (Did you use the same
subjects in each condition ? )))
((which-template find (dt _r) (_r) (What was the nature of
your data ? )))
((which-template find (dk _r) (_r) (What type of data did
you collect ? )))
((which-template find (dd _r) (_r) (Did your data have a
normal,or near normal distribution ? )))
((which-template find (dv _r) (_r) (Was there homogeneity of
variance ? )))
((which-template find (samp _r) (_r) (What type of samples
did you use ? )))

/* (natural language templates for explanations)
/*()
((cl-read-as ((answered _rel _res)(find _rel _ans)("help?"
_rel _ans _res)) (" "¦_z)_z))
((read-as answered (_a _b)(_comment¦_z)_z)(com-for _a _b
_comment))
((read-as find (_a _b)(you answered that question¦_z)_z)(VAR
_b))
((read-as find (_a _b)("~B" _b "~D" in answer to that
question¦_z)_z))

/* (wording for natural language templates)
/* ()
((com-for dtype1 yes "you wanted to compare average
performance"))
((com-for dtype1 no "you didnt want to compare average
performance"))
((com-for dtype2 yes "you were looking for a correlation
between variables"))
((com-for dtype2 no "you werent looking for a correlation
between variables"))
((com-for dtype3 yes "you collected your data into
categories"))
((com-for dtype3 no "you did not collect your data into
categories"))

((com-for ncons not-sure "you were not sure about the number
of conditions"))
((com-for ncons two "your experiment had two conditions"))
((com-for ncons "more than two" "your experiment had more
than two conditions"))
```

```
((com-for c1 yes "you had a single experimental and a single
control condition"))
((com-for c1 no "you didnt have a single experimental
condition"))
((com-for c2 yes "you had a single control condition"))
((com-for c2 no "you didnt have a single control
condition"))
((com-for c3 yes "you had more than one control condition"))
((com-for c3 no "you had a strange type of experiment"))

((com-for dt not-sure "you were not sure about the nature of
your data"))
((com-for dt parametric "your data was parametric"))
((com-for dt non-parametric "your data was non-parametric"))

((com-for dk "interval or ratio" "you had data of interval
or ratio type"))
((com-for dk other "you had a type of data other than
interval or ratio"))
((com-for dd "normal or near normal" "your data was
approximately normal"))
((com-for dd "not normal" "your data was not normal"))
((com-for dv homogeneous "your samples had similar
variances"))
((com-for dv "not homogeneous" "your samples did not have
similar variances"))

((com-for subs same "you said so"))
((com-for subs different "you said so"))

((com-for vars one "your experiment had one variable"))
((com-for vars "two or more" "your experiment had two or
more variables"))

((com-for samp matched "your experimental samples were
matched"))
((com-for samp unmatched "your experimental samples were
unmatched"))

/* (clause indicating that 'find' is a function)
/* (- means that only one answer will be accepted)
/* ()
((FUNC find ))
```

```
/* (Statistics Expert System)
/* (        Part 3           )

/* (   (C) MHA SMITH , 1987   )

/* (forces system to redraw windows)
/* (used after display has become corrupted)
/* ()
((bloop now)
  (IF (CL((needtotidy true)))
       ((PUTB "WND:" 23)(PUTB "WND:" 7)(DELCL ((needtotidy
true))))
       ()))

/* (defines the help option)
/* ()
(("help?" _rel HELP _bak)
  (aid _rel)
  (scrub-dialog _rel)
  (find _rel _temp)
  ("help?" _rel _temp _bak))

(("help?" _rel _ans _ans))

/* (removes irrelevant dialogue relating to help)
/* ()
((scrub-dialog _rel)
 (DELCL((find _rel HELP)))
 (DELCL((asked find _z))))

/* (ways in which help is provided)
/* ()
((aid dd)(run exnorm))
((aid dv)(run exvar))
((aid _rel)
 (explained-in _rel _file  _wnd)
 (exwind _wnd ¦_par)
 ("?BROWSE?" _file HELP ¦_par))

((run _notes)
 (EXEC "run.exe" (_notes) _r)
 (tidy windows))

((tidy windows)
 (ADDCL((needtotidy true))))
```

```
/* (names of files of help text)
((explained-in dtype1 "sta1.txt" standard))
((explained-in dtype2 "sta2.txt" standard))
((explained-in dtype3 "sta3.txt" standard))
((explained-in vars "sta4.txt" type1))
((explained-in ncons "sta5.txt" standard))
((explained-in c1 "sta6.txt" standard))
((explained-in c2 "sta7.txt" standard))
((explained-in c3 "sta8.txt" type2))
((explained-in subs "sta9.txt" standard))
((explained-in samp "sta10.txt" type1))
((explained-in dk "sta11.txt" standard))

/* (window definitions for help text)
((exwind standard 5 10 16 60))
((exwind type1 5 10 18 60))
((exwind type2 5 10 5 60))

/* (template for help relation)
/* ()
((read-as "help?" (_a _b _c)("~M~Y"¦_z)_z))

/* (system definitions of relations)
/* ()
((non-int aid))
((non-int scrub-dialog))
((non-int help-with))
((non-int run))
((non-int tidy))
((non-int explain))
((non-int exwind))

((dict "help?"))
```

```
/* (Statistics Expert System)
/* (        Part 4           )

/* (  (C) MHA SMITH , 1987   )

/* (supervisor)
/* ()
(("<USER>")
 (re set)
 (check start)
 (open comm-win)
 (is-action _action)
 (shut comm-win)
 (OR((do-action _action))
 ((P "")))
/("<USER>"))

/* (resets the system, deleting any previous dialogue)
/* ()
((re set)
 (close windows)
 (FORALL((asked _rel _z))((KILL _rel)))
 (KILL asked))

/* (first-time help)
/* ()
((check start)
 (OR((first time)(first help))()))

((first time))

((first help)
 (help screen1)
 (DELCL((first time))))

/* (main-menu screen layout)
/* ()
((open comm-win)
 (CURSOR base 1 45)
 (W base ("- program options          "))
 (CRWIND commands 6 20 12 40 0 0)
 (CURSOR  commands 1 2)
 (P Choose one of the following:))
```

```
/* (main-menu actions)
/* ()
((do-action " find a suitable test")(CURSOR base 1 45)(W
base ("- finding a suitable test  ")) ("?find?"( You should
use the _t test : uses-test (_t))))
((do-action " check suitability of a test")(CURSOR base 1
45)(W base ("- confirming use of a test "))(open
testchoice)(t-to-confirm _test)(P "~L")(CURSOR tc 0 0)(P
checking use of the _test test) ("?confirm?"(uses-test
(_test)))(shut testchoice))
((do-action " leave the program")(CURSOR base 1 45)(W base
("- leaving the program        ")) ("?QUIT?"))
((do-action " how to use this program")(CURSOR base 1 45)(W
base ("- giving some help          "))(help screens))

/* (start-up menu actions)
/* ()
((do-action " do nothing ")(close windows)(help screen1))
((do-action " get started ")(close windows))

/* (help menu actions)
/* ()
((do-action " NO MORE HELP")(close windows))
((do-action " what are Expert Systems ?")(hp-with es)(shut
help-win)(help screens))
((do-action " how do I get an explanation of the result
?")(help ex)(shut help-win)(help screens))
((do-action " how can I check the use of a test ?")(hp-with
check)(shut help-win)(help screens))
((do-action " how can I find a suitable test ?")(hp-with
find)(shut help-win)(help screens))
((do-action " - ")(shut help-win)(help screens))

/* (help window screen layout)
/* ()
((open help-win)
 (CRWIND help-choice 6 10 14 60 0 0)
 (CURSOR help-choice 1 2)
 (P Choose one of the following:))

/* (choice of tests screen layout)
/* ()
((open testchoice)
 (CRWIND tc 4 10 1 50 144 0)
 (CURSOR tc 0 10)
 (P Which test do you think is correct?))
```

```
/* (closing of various windows)
/* ()
((shut comm-win)
 (CUWIND base)
 (CLOSE commands))
((shut help-win)
 (CUWIND base)
 (CLOSE help-choice))
((shut testchoice)
 (CUWIND base)
 (CLOSE tc))

/* (closing all windows except for base window)
/* ()
((close windows)
 (CUWIND base)
 (WDICT | _wlist)
 (FORALL ((ON _wind _wlist)(NOT perm _wind))
        ((CLOSE _wind))))
((perm _wind)
  (ON _wind (base)))

/* (HOW TO USE THE PROGRAM options)
/* ()
((help screens)
 (open help-win)
 (info _a)
 (do-action _a))

/* (- getting an explanation)
/* ()
((help ex)
 (EQ _win " how to use the program ")
 (CRWIND _win 5 5 17 70 0 0)
 (CURSOR _win 1 20)
 (P "~B"Getting an Explanation"~D")
 (CURSOR _win 3 2)
 (P When the system has displayed its conclusion you can
then make it)
 (CURSOR _win 4 1)
 (P produce an explanation of how it did so.)
 (CURSOR _win 5 2)
 (P You select "~R"how"~D" from the menu.)
 (CURSOR _win 6 2)
 (P You should then be able to follow the rules that the
system used.)
 (CURSOR _win 8 25)
 (P OPTIONS DURING EXPLANATIONS)
 (CURSOR _win 9 25)
 (P "---------------------------")
 (CURSOR _win 10 10)
 (P "~R"ok"~D" "     " go back one step in the explanation)
 (CURSOR _win 12 10)
 (P "~R"1"~D" "      " explanation of statement 1 "(or 2 or 3
etc.)")
```

```
 (CURSOR _win 14 10)
 (P "~R"stop"~D" "   " stop the explanation)
 (pause)
 (CUWIND base)
 (CLOSE _win))

/* (start-up help)
/* ()
((help screen1)
 (CRWIND " sc1 " 4 0 19 78 0 0)
 (CURSOR " sc1 " 2 25)
 (P  Statistical Tests Expert )
 (CURSOR " sc1 " 3 25)
 (P  "----------------------")
 (CURSOR " sc1 " 5 10)
 (P "~B" Using menus . . . "~D")
 (CURSOR " sc1 " 7 20)
 (P Press ENTER to SELECT HIGHLIGHTED ITEM)
 (CURSOR " sc1 " 9 20)
 (P Press SPACE to move HIGHLIGHT DOWN)
 (CURSOR " sc1 " 11 20)
 (P Press BACKSPACE to move HIGHLIGHT UP)
 (CURSOR " sc1 " 16 15)
 (P Make your selection from this menu)
 (help-next _a)
 (do-action _a))

/* (indicates where help text is)
/* ()
((hp-with _subject)
 (helped-by _subject _file)
 ("?BROWSE?" _file " How to use the program " 5 5 17 70))

((helped-by es "start4.txt"))
((helped-by find "start5.txt"))
((helped-by check "start6.txt"))

/* (menu options - CHECK USE OF A TEST)
/* ()
((in-fmenu t-to-confirm (_a) (_a) (("Friedman" "Page's L
Trend" "Kruskal-Wallis" "1-way ANOVA (related)" "1-way ANOVA
(unrelated)" "2-way ANOVA (related)" "2-way ANOVA
(unrelated)" "Student t (related)" "Student t (unrelated)"
"Mann-Whitney U" "Wilcoxon T" "Spearman's correlation rho"
"Pearson's correlation r" "Chi-squared") tests 7 31 14 27 0
1)/))

/* (menu options - MAIN MENU)
/* ()
((in-fmenu is-action (_a) (_a) ((" how to use this program"
"   " " find a suitable test" "   " " check suitability of a
test" "   " " leave the program") choice 9 22 7 35 144 1)/))
((in-fmenu help-next (_a) (_a) ((" do nothing " " get
started ") choose 20 60 2 15 0 1)/))
```

```
/* (menu options - HOW TO USE THE PROGRAM)
/* ()
((in-fmenu info (_a) (_a) ((" how can I find a suitable test
?" " - " " how can I check the use of a test ?" " - " " how
do I get an explanation of the result ?" " - " " what are
Expert Systems ?" " - " " NO MORE HELP") choice 9 15 9 50
144 1)/))

/* (system definitions)
/* ()
((front is-action))
((front t-to-confirm))
((front help-next))
((front info))
((HOME base))
```

(Explanation of normal data - written in RM PASCAL)

```
PROGRAM normal;

CONST PI=3.14;
VAR k,stepsno,ox,oy,x0,y0,x1,y1,t:INTEGER;
u,v:REAL;

PROCEDURE hitakey(VAR t:INTEGER);
 BEGIN
  CURPOS(33,25);
  WRITE('<Press any key>');
  FLUSH;
  t:=TIMEKEY(10000);
 END;
BEGIN
 stepsno:=96;
 ox:=32; oy:=40;
 MODE(HRES,GRAPHIC);

 CURPOS(0,2);
 WRITELN('              An important requirement for data
which is to be tested');
 WRITELN('            using parametric techniques is that
its distribution be');
 WRITELN('            normal, or at least near normal.');
 WRITELN;
 WRITELN;
 WRITELN;
 WRITELN('              A normal distribution looks like
this:');

 CANVAS(0,170,639,20);
 LINE(ox,oy-2,ox+560,oy-2);
 LINE(ox,oy-2,ox,oy+90);
 x0:=ox ; y0:=oy;
 PLOT(16,80,'f');
 FOR k:=0 TO stepsno DO
 BEGIN
   u:=(k-stepsno/2)/(stepsno/8);
   v:=EXP((u*u)/(-2))/SQRT(2*PI);
   x1:=2*ROUND(ox+k*256/stepsno);
   y1:=ROUND(v*180+oy);
   LINE(x0,y0,x1,y1);
   x0:=x1;  y0:=y1
 END;
 LINESTYLE(2,0);
 LINE(ox+290,oy+80,ox+290,oy);
 hitakey(t);
 MODE(80,TEXTUAL);
 CURPOS(0,5);
 WRITELN('                        In some situations, particularly
in');
 WRITELN('                       the case of small samples, it is');
 WRITELN('                       unreasonable to make the
assumption');
 WRITELN('                       that the data is normally
distributed.');
 WRITELN;
 WRITELN;
 WRITELN('                        You can use the CHI-SQUARE test
to');
 WRITELN('                       check if the data has a normal
(or');
 WRITELN('                       near normal) distribution.');
 hitakey(t);
 MODE(80,TEXTUAL);
 WRITE( CHR(27),'c')
END.
```

Comparison of average performances◆

One way of comparing groups is to measure the performance of each member of the group on a particular test and to compare the average performances for each group.

The average can only be calculated when individual performances can be measured and thus placed in some kind of order in relation to other performances.

A number of ways of measuring are possible.......

example given on next page
(Select 2 from menu)

For example:- one may wish to compare two groups of students by means of their ability to carry out tasks in a given test. A particular student's performance in this test could be measured in a variety of ways.

i) The time taken to complete all the tasks correctly.

ii) A point could be given for each task carried out correctly and these totalled to provide an overall score for the test.

iii) A grade could be given to each student's performance. The grading method would have to imply an order -
example A , B , C , D , E (A-best....E-worst)

Connection between variables◆

Sometimes one is interested in the connection between two variables such that ....

the presence of one variable is associated with the presence of the other (positive correlation◆);

OR the presence of one variable is associated with the absence of the other variable (negative correlation◆);

OR the presence of one variable has no particular association with the presence of the other.

examples given on next page

examples:

The distance travelled by a motor car and the average speed of the car shows a high positive◆ correlation.

The fuel consumption in miles per gallon and the average speed show a high negative◆ correlation.

The fuel consumption and the number of hours of sunshine show no particular association - low◆ correlation.

Counting individual occurences◆

By counting individual occurences into categories one can assess whether two groups appear to exhibit the same behaviour in respect of that thing which you were observing.

an example is given on the next page

example:

Do women drivers stop more often at amber traffic lights than men drivers ?

By counting the number of occurences where women drivers did or did not stop as well as counting the number of occurences where men drivers did or did not stop, one would have categorised the stopping behaviour by sex of subject.

	Stopped	Did not stop
Men	25	37
Women	37	8

Number of variables◆

An experiment has one variable◆ if you are testing the effect of A (one variable) on B (some form of measurable performance provided by the subject).

for example- One might be interested in the effect of increased noise (the experimental variable) on mental arithmetic skill (the measurable performance).

An experiment has two variables◆ if you are testing the
effect of A or B (two variables) on C
or A and B on C

for example- the effect of practice (one experimental variable and IQ (the other variable) on the performance of a skill.

Number of conditions◆

Experimental conditions are those aspects of an experiment that you, as the experimenter, have control over. The number of conditions is the same as the number of different treatments that you apply to the groups in your experiment.

Typically you may have:

TWO CONDITIONS :A single experimental condition and a control condition.

MORE THAN TWO CONDITIONS : Two or more experimental conditions and one or more control conditions.

Experimental Design◆

The experimental design that you will come across most frequently is the one where there are two conditions.

One group is subjected to a particular kind of treatment (the experimental condition), the other group does not receive the treatment (the control condition).

example:
If you were investigating the effect of a stimulant drug on a learning task;

Group A (Experimental)	25 mls of drug
Group B (Control)	NO drug

Experimental Design◆

Two (or more) experimental conditions and one control condition – although you will come across this type of design less often it is frequently used.

example:
You may have two experimental conditions where two groups receive different levels of the variable under investigation.

Group A		50 mls of drug
Group B		25 mls of drug
Group C	(control)	NO drug

Experimental Design◆

Two or more experimental conditions and a number of control conditions are used in some experiments.

Subjects◆

The same subjects are used in the repeated measures design of experiment. Two scores are obtained from every subject.

This is a very strong design since it controls for subject variability◆ since the same person is tested before and after the introduction of the variable.

This is also known as the WITHIN SUBJECTS design.

more on next page

Where repeated measures design is impossible because of a learning factor from task 1 to task 2 then different subjects have to be used.

This is known as the BETWEEN SUBJECTS design.

Matched or Not matched◆

Where repeated measures design is not possible, the Matched Pair◆ design is thought to be the next best.

By pre-testing the subjects before the experiment they can then be placed into the experimental or control group on the basis of their pre-test scores. These two groups of subjects can then be deemed to be of similar ability. Any change in performance by the experimental group can be deduced to have been caused by the variable under investigation and not differential ability within the two groups.
This is not always possible, in this situation the experiment has to use unmatched subjects.

Type of Data◆

The data you collected from your experiment may not be suitable for some kinds of test.

If you measured individual performances and obtained some kind of score for each then it is likely that your data is of interval or ratio◆ type.

On the other hand, if you simply categorised the performances or collected your data by placing your observations into categories then your data will be of some other◆ type.

Expert Systems◆

Expert systems are designed to allow a computer to hold knowledge and expertise of a particular subject. This can then be used to give advice to people who are not experts.

This advice might consist of what to do in particular situations and an explanation of why those suggestions were made.

One early expert system was designed to help doctors diagnose bacterial infections in the blood. The expert system would ask the doctor various questions about the nature of the symptoms, the patient etc.

Using the facts and rules telling it how to apply those facts the system then suggested a diagnosis and treatment. It was also able to explain why it was asking particular questions and why it had reached its conclusions.

Finding a Suitable Test◆

This expert system holds some knowledge about statistical tests and the circumstances in which each should be used.

You will be asked a number of questions relating to the experiment that you carried out and its data. When each question is asked you will see a list of possible answers. You MUST choose one of them.

If you do not understand the question or are not sure of the answer you should select HELP◆ - this will provide you with some useful information.

From your answers the system will work out which test, if any, would be suitable.

You may then find out how the system came to its decision by selecting the how◆ option.

Checking the use of a test◆

You can use the system to check whether or not the test you have chosen is suitable for your experiment.

First you will be asked to select your chosen test from a list of tests about which the system has information.

Next you will have to answer a number of questions, choosing the appropriate reply from those provided. The system will then confirm or fail to confirm your choice of test.

You can investigate the way in which the system came to its conclusion by choosing the how◆ option.

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APPENDIX

Notes for the assessor

The system supplied for assessment differs only in one respect from that used in the classroom. Due to the uncertainty about the configuration of the machine that would be used, this version does not make use of the RM "Silicon Disc" facility.

This has the effect of slowing down the display of HELP text; using silicon disc access to these files is virtually instantaneous.

This version requires: RM Nimbus running MS-DOS.

A batch file has been included on the disc, so simply enter STATS to start the system.