CONVERSATIONAL COMPUTER TERMINALS
IN PSYCHOLOGICAL TESTING

by

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ABSTRACT

The concept of CCTT (conversational computer terminal testing) is investigated as a practical and advantageous solution to the problem of administrating a statistically complex testing model, which will minimize the time losses and delays of conventional psychological testing.

In the process of personnel selection, larger organizations often invite certain of their applicants to undergo psychological testing. This usually involves inconvenience for the applicant, additional expense for the organization, and time losses for both. The testing procedure will typically be of a fixed treatment, group testing nature whereas for many applicants an adaptive testing procedure would be more appropriate. Although testing mechanisms for adaptive treatments exist, they tend to be awkward and limited. More sophisticated theoretical models have been developed but tend to lack appropriate means of administration.

In this investigation a Fortran IV CCTT probability/sequential model is developed and comparisons are made between CCTT and conventional test administration of verbal and numerical analogy tests to 180 subjects. The CCTT model presents an applicant with a test item, scores the response, and statistically computes and predicts group membership within pre-definable accuracy levels. The three possible
classifications and associated treatments are: high scorer, administer next test; low scorer, terminate testing; unclassified, continue present test.

Findings of the investigation indicate that there are no significant differences in overall test scores between the two methods of test administration. The CCTT model is able to classify individuals with an accuracy level exceeding 80% on both verbal and numerical tests after only 25% of the test items have been administered, with a resultant reduction in testing time of 65%. Additionally, CCTT offers the benefits of individualized demand testing, automatic scoring and recording, complex and tailored decision branching, and immediate interpretation of results.

Suggestions for further research in this and associated areas are provided.
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CHAPTER I

INTRODUCTION

I THE PERSONNEL SELECTION PROCESS

Typically, the personnel selection process of today involves a sequence of events which an applicant must survive if he is to be successful in his bid for a particular position. Although the order, extent and emphasis of these events may vary, there are several that can be considered representative of the medium to large sized organization. These are the application blank, personal interviews, psychological tests, reference checks, and medical examination. What each of these selection tools is ultimately attempting to assist in is the prediction of an applicant's performance or potential for performance within a given task range. Failure to pass any one of these obstacles will usually mean elimination from the balance of the selection process, particularly where a large number of other applicants are available.

Many variations of this typical process exist but most are sequential with fewer applicants being considered at each subsequent stage.
II THE PROBLEM

The personnel selection process is a time consuming and costly procedure both from the point of view of the selecting organization and of the applicant. When these processes are conducted in a sequential, step by step manner, varying time lapses will usually occur between each step.

For example, when an applicant completes and submits an application he is not normally given an immediate interview but rather is required to await a possible invitation for one. Once interviewed he may next be invited to complete a few psychological tests but this often involves a return trip for a scheduled group testing session. After testing it can be another day or two before the results have been scored and interpreted and these in turn may lead to a further interview, reference checking, and ultimately a job offer (usually subject to passing a medical).

Elimination of the applicant may come after any of the above steps with an early rejection favorable to both parties. From the organization's point of view, each additional step leading to an ultimate rejection only adds to the cost of final selection. Time lost between steps
also tends to reduce the probability that the applicant will remain available for hire, particularly if he is actively seeking employment elsewhere. From the applicant's side, early rejection eliminates further and unnecessary consumption of his time. This is of particular importance when he is currently employed and must take time off for interviews and tests.

Of the actual steps in the above selection process psychological testing is perhaps the most time consuming and uncomfortable for the job applicant. The application blank merely requests biographical data and about fifteen minutes of the applicant's time. The interview can vary but generally duplicates application data to some extent, takes fifteen to fifty minutes, and provides the applicant with some information in return. Reference checking is normally transparent to the applicant and medicals are usually only given once a conditional offer of employment has been extended. Psychological tests on the other hand may require from one-half to five or six hours of what many consider probing, pressured, and even exhaustive exercise. Often when test results are finally analyzed it becomes evident that further testing in a specific area would have been desirable or that certain tests were not really required. It is not uncommon for an applicant to
be eliminated on the basis of specific tests (e.g., abilities) but because these tests cannot be immediately scored and interpreted the remaining tests must also be completed. Furthermore, many conventional psychological tests tend to be somewhat inefficient as they are designed to measure a given trait across a wide range of levels. This leads to higher-scoring individuals wasting time answering easy items while low-scorers may guess at difficult items.

Several theoretical or partial solutions to these problems have existed for some time. Among them are the techniques of 'programmed' and 'multi-stage' testing. With programmed tests the subject is guided to items of an appropriate difficulty level through a system of sequential branching. If he gets an item right he proceeds to a more difficult one and if wrong, to an easier one. Typically, the range of difficulty between successive items normally decreases. In multi-stage testing, administration and content of successive tests is determined by performance on preceding tests. This allows subsequent tests to be matched to the subject's ability level.

The difficulties with these and other solutions have been in the actual administration of the tests. Lord (1971a) suggests a cumbersome paper-and-pencil procedure for two-stage testing. The answer sheet for the first test is
completed in duplicate with the original being immediately collected for later scoring as the official record of performance. The duplicate is scored by the examinee according to instructions provided by the examiner and this score determines the second-stage test to be administered.

Hubbard (1963), encountering problems in programmed test administration developed a rather unique solution. The answer sheet consisted of a series of inked blocks, each numbered to correspond to the possible answers. When the examinee made his choice he simply erased the appropriate ink block revealing the number of the next test question to be attempted. Annett (1964) developed a similar solution utilizing a grid device with numbers embossed onto a metal or plastic matrix. The answer sheet was pasted over the grid and the examinee rubbed a soft pencil over his chosen answer, thus exposing the hidden number directing him to the next test item.

Such methods have provided limited means of tailoring and shortening psychological tests. What is still required however, is a form of demand testing not requiring the services of a full time test administrator and psychologist, yet capable of instantaneous scoring, tailoring, interpretation, and feedback while shortening the tests. Additionally, such testing should be capable of applying the more sophist-
icated statistical decision models that are available today.

III PROPOSED SOLUTION

In the field of psychological tests, computers have been put to work in such areas as scoring, interpreting, validating, and even developing tests. Limited use however, has been made of the computer as a test administrator. It is proposed that through the use of conversational computer terminal testing (CCTT) many of the preceding problems could be solved.

CCTT is a process which permits demand testing with the facility to make immediate decisions, to branch to other tests where required and to provide instantaneous test interpretation and feedback. CCTT can eliminate the time lapses on either side of psychological testing in the personnel environment and appears to have the capacity to shorten tests and enhance their quality.

Under the concept of CCTT, when an applicant is identified for psychological testing (usually during the interview) he is simply seated at a CCT with a few instructions (verbal, printed or displayed on the terminal) and the computer does the rest. CCTT will teach the applicant how to operate the terminal in a matter of seconds and will
then administer the appropriate tests. The possible
testing models are virtually limitless as is discussed in
Chapter three.

As the terminal administers the test items the computer
scores and analyzes each response. It constantly monitors
performance, deciding whether further testing is required and
if so, in what areas. Thus testing is tailored for the
applicant as he proceeds and it can be terminated as soon as
sufficient decision information has been collected. Even
while the applicant is still working at the CCT a complete
test evaluation can be printed at a remote terminal.

It is conceivable that a logical extension of the CCTT
concept would be the development of a CCTS/P (Conversational
Computer Terminal Selection/Placement) model. Such an
integrated and comprehensive model could be used to collect
biographical and other data normally gathered from the
application blank, interviews, testing, and even pre-medical.
While attempting to decide if an applicant was acceptable
for employment the model would also be determining the most
suitable areas of placement and whether such vacancies existed
or were likely to in the near future.

This paper is, however, confined to the development
and testing of a single CCTT model. Utilizing one type of
test it primarily explores whether significant differences
in performance occur between paper and computer administra-
tions and whether significant reductions in testing
time can be realized using CCTT. Relative costs of CCTT
are also examined.
CHAPTER II

REVIEW OF THE PERTINENT LITERATURE

I STATISTICAL DECISION THEORY

Statistical decision theory, originated by Abraham Wald in the late 1930's (Girshick, 1954), is still a relatively young and incomplete science. Wald (1950) investigated problems of inspection and quality control where either an acceptance or rejection decision was required. Clearly, the personnel selection process outlined in Chapter I requires a similar ultimate decision and one of the mechanisms by which that decision may be reached is psychological testing. In arriving at this ultimate decision, each of the above processes may utilize a third alternative when the decision to accept or reject is not clear-cut, that is, to continue the process by collecting more information.

Typically this is what happens in the overall sequential selection process but not in the testing segment. Here, a pre-determined amount of test data is first collected and analyzed, and then an accept/reject decision is made. This is inefficient, however, as usually more than the required amount of information to reach a decision is collected or occasionally it is discovered, after the fact, that sufficient
test information was not gathered. Thus exists the case for sequential testing strategies.

A strategy must state what the decision maker will do in any possible contingency (Girshick, 1954, p. 464) and normally consists of a set of conditional probabilities, (Cronbach and Gleser, 1965, p. 19) each between 0 and 1. Although probabilities may be classified as either objective or subjective (Levin and Kirkpatrick, 1965), the concern here is with the former. These are referred to as assigned probabilities that are supported by historical evidence and common experience, or are self-evident from the physical attribute of the system. They indicate the chance of an event happening.

II APPLICATION TO PSYCHOLOGICAL TESTING

Sequential testing

One form of sequential testing is referred to as programmed testing. This involves a sequential system of branching which guides the subject to test items of an appropriate difficulty level. Cleary, Linn, and Rock (1968, p. 183) indicate that programmed tests have the capacity to significantly reduce testing time required for ability assessment, to reduce the component of unreliable variance due to random guessing, and to increase the accuracy of
measurement near cut-offs by having subjects respond to additional items. In its simplest form a programmed test consists of a routing section where the necessary branching takes place to direct the subject to the appropriate level of test items and a measurement section which concentrates these items.

Lord (1968) has appropriately labelled this form of sequential testing 'tailored-testing' where an attempt is made to 'tailor' the difficulty of the test items to the 'ability' of the individual being tested. He indicates (Lord, 1971, p. 4) that considerable work remains to be done in determining what the initial difficulty level should be, how much the difficulty level should change after any right or wrong answer, how responses should be scored, and how the effectiveness of the possible procedures should be compared.

A 'less-tailored' form of tailored-testing is sequential two-stage testing. This procedure calls for a routing test followed by one of several alternative second-stage conventional tests. Cronbach and Gleser (1965, Chapter 6) explore two-stage testing as a sequential decision theory technique whereby examinees may be classified after the first test into accept, reject, or continue testing categories. The main advantages of this procedure are a savings in testing time and elimination of unnecessary tests.
A sequential model that has been shown theoretically capable of reducing the number of test items by one-half is a probability approach by Linn, Rock and Cleary (1972). This type of approach has, however, lacked an appropriate mechanism for its administration. CCTT appears to provide this mechanism and thus a sequential probability model is explored more fully in subsequent chapters.

Paitich (1973) presents a computer program capable of generating automatic psychological reports for a battery of measures of intelligence and personality. The various tests are interpreted by rather simple procedures that involve printing given sentences or short paragraphs that correspond to scores falling within a specified range. Hedl, O'Neil and Hansen (1971a) have developed an automated administration and scoring program for the Slosson Intelligence Test (Slosson, 1963). A considerable amount of work has also been done on computerized interpretation of the Minnesota Multiphasic Personality Inventory (MMPI) (Hansen, Hedl and O'Neil, 1971), but only recently has an attempt been made to computerize its administration (Dunn, Lushene and O'Neil, 1972). It was found that the test could be successfully administered and scored in this manner although the study itself was mainly concerned with latency analysis. Waters (1970) in a comparison of computer-simulated branching and conventional
tests of varied lengths found branching tests had higher correlation with underlying ability than did any of the conventional tests. Gedye and Miller (1969, pp. 258-259) indicated automated testing is probably justified on economic grounds and also found subjects of all ages favorably disposed to automated testing. Elwood (1972) found automated administration of the Wechsler Adult Intelligence Scale (WAIS) was indeed cheaper than face-to-face administration by a factor of one-half. Hedl, O'Neil and Hansen (1971b) have, however, found that computer testing procedures can lead to higher levels of anxiety.

Several of the above findings have resulted from computer-assisted instruction (CAI) applications but most have been generated by a need to improve selection and testing procedures. Other identified horizons for related CCT applications are in the fields of counselling (Veldman and Menaker, 1968; Ellis and Tiedeman, 1970), and medical history and diagnosis (Edwards, 1968; Mayne, Weksel and Sholtz, 1968).
CHAPTER III

POSSIBLE COMPUTERIZED TESTING MODELS

In the preceding discussion of statistical decision theory, three main classes of decisions were presented. These were sequential two-stage, probability, and branching decisions. The present chapter is intended to indicate some of the possible CCTT models that could result from such decision patterns.

I MODELS

Single stage

The typical testing model in the field of personnel selection today is one of fixed-treatment. The individual completes a series of tests, they are analyzed and a decision is made to hire or not hire. As discussed in Chapter I this model is inefficient for several reasons. To computerize it would be of minimal benefit.

Sequential multi-stage

In sequential multi-stage testing a decision is possible and normally expected after each stage. Typically this decision is to either suspend testing or to continue and is based on test performance to that point with fewer individuals being tested at each stage. Simple cut-off scores can exist
for each test and cumulative scores are also possible. Although the two stage version of this model is sometimes applied in psychological testing, it is awkward, and multi-stage applications of it are very much more so. Although such a model is readily computerized it does lack some efficiency in that entire stages of the test must still be given.

**Probability/sequential single stage**

This model is based on probability of group membership and is virtually impossible to administer in a conventional setting, due to the moderately complex statistical calculations required after each response. It is on the other hand very readily computerized and theoretically capable of a 50% reduction in the number of test items required as referenced in the previous chapter. The decision reached by this model is dichotomous (accept or reject).

**Probability mult-stage**

This is identical to the preceding single stage model except that a third alternative decision is now possible and that is to continue testing with the next stage. This type of model is developed in Chapter IV.

**Branching multi-stage**

The branching multi-stage model adds two new decision
dimensions in that it determines which test or item(s) will be administered next. Thus it is capable of tailoring tests within and across subject areas.

**Complexity/branching**

This type of model involves branching to other items, tests or treatments based on what could be complex statistical calculations resulting from answer patterns, associated latencies, previous performance, biographical and test data, interview reservations and so on. Considerable developmental work will be required before this type of model becomes a reality. It begins to encompass analysis of data collected in other aspects of the selection process and attempts to duplicate or make the Personnel Manager's selection for him.

**II SUMMARY**

The above models were briefly described to illustrate the apparent capabilities of CCTT. Considerably more research will be required on the concept to examine its feasibility, applicability, and acceptability.
CHAPTER IV

COMPUTERIZED DEMONSTRATION MODEL

I PURPOSE

A multi-stage probability/sequential computerized testing model was developed for several purposes, namely:
- to demonstrate that psychological tests with a multiple-choice format could readily be administered, scored, interpreted, and recorded by means of CCTT;
- to investigate what effects if any CCTT would have on overall test performance;
- to determine if significant time savings in test administration could be realized through use of a probability/sequential CCTT model;
- to obtain some relative measure of testing costs using CCTT.

II LIMITATIONS

As discussed in the preceding chapter the degree of complexity of CCTT model can be almost limitless. For purposes of demonstration however, a simple probability/sequential decision model was chosen. Only one type of psy-
chological test (2 forms) was used and a simple pass/fail criterion was developed. To facilitate complete data collection, the test-cutoff and multi-stage decision options of the model were not activated. Thus in addition to predicting final performance, the model was used to actually determine a subject's final performance as well.

III DESIGN

Classification procedure

The design of the probability/sequential decision model incorporated a technique developed by Armitage (1950) and recently applied in research on sequential testing for dichotomous decisions (Linn, Rock, and Cleary, 1972). Basically the technique requires that a calibration sample be collected, scored, and split into high and low scoring groups. It is then possible to prepare estimates of each item's difficulty for each group by simply calculating the proportion of subjects in each group who answer that item correctly.

Letting $P_{hi}$ be the proportion of calibration subjects in the high scoring group who answer item $i$ of the test correctly and $P_{li}$ be the proportion of calibration subjects in the low scoring group who answer item $i$ of the test correctly, additional subjects may be tested and classified
as follows:

1. test item i is presented to and answered by the subject;
2. test item i is scored;
3. the subject is assigned to the high group after the nth item if:

\[ f(n) = \sum_{i=1}^{n} \log R_i > A, \]

and to the low group if:

\[ f(n) = \sum_{i=1}^{n} \log R_i < -A \]

where \( R_i = (P_{hi}/P_{li}) \) if the response to test item i is correct, \( R_i = ((1-P_{hi})/(1-P_{li})) \) if the response to test item i is incorrect, and \( A \) is a constant.

If assignment is not made then another test item \((i+1)\) is presented to the subject. This process is continued either until a subject is classified, or the end of the test is reached, at which point classification is to the high group if \( f(n) \geq 0 \) and to the low group if \( f(n) < 0 \).

If test items were of equal difficulty then \( A \) values of 1.39, 2.30, 3.00, and 4.61 would correspond to upper bounds on the probabilities of misclassification of .25, .10,
.05, and .01 respectively (Linn, et al., p.89). As the test items used for this research project were not of equal difficulty it may only be stated that there is an inverse relationship between the value of A and the error probabilities. This is not a serious limitation however, as the value of A may be easily adjusted to provide the desired level of accuracy in classification.

At any given value of A the accuracy level may be found by simply determining what percentage of subjects have been correctly classified. The value of A may then be adjusted accordingly and the percentage recalculated, repeating this process until an A value is determined for the desired level of accuracy in classification. As this level increases however, so should the average number of test items required for classification.

Psychological Tests

Only two criteria were used in selecting tests for demonstrating the model. The first was that the tests should utilize multiple-choice format answers to facilitate input to the computer. Secondly, it was desirable that the tests should be of a difficulty level such that there would be sufficient variance in the observed test scores. What the tests actually measured was not critical to the design. As the model was only designed to predict overall score on
the tests being administered, other criteria were not required.

The tests chosen for the demonstration were the Verbal and Numerical forms of the Minnesota Multimodal Analogy Test-1971 Revision (Appendix A). Only the first forty items from each form were used to allow for classroom administration in gathering the calibration sample.

Computer model

A Fortran IV computer model (Appendix B) was developed to perform the following functions from a video screen conversational computer terminal (IBM 3270);

1. determine that the subject is genuine and has not previously undergone the computerized testing;
2. determine order of test administration according to subject's identification;
3. administer test instructions and sample questions;
4. administer test items, one at a time;
5. perform statistical analysis after each response to determine if subject can be classified (and test terminated);
6. store testing data in a file (unique to that subject) after each test response;
7. present termination message to subject.
An identification file is created which consists of each subject's section and student number. A subject 'signs-on' to the conversational computer terminal using printed instructions (Appendix C) to operate the terminal's keyboard. The computer then requests the subject's student and section numbers by displaying instructions on the terminal's video screen. Next a storage file is created by the computer using the subject's identification number as the file name, and the calendar date and time of day are entered on the file. If the subject's number cannot be found in the identification file (which indicates he is probably not a genuine subject) or if a storage file for that number already exists (which means the subject has previously undergone the computerized testing) an appropriate message is returned to the screen and the subject is automatically 'signed-off' the terminal.

The verbal and numerical analogy tests and associated instructions reside in separate computer storage files (Appendix D). The order in which the tests are administered is determined by the subject's section number. Instructions for the first tests are then displayed on the terminal screen along with a sample question. These remain on the screen until the subject depresses a key indicating he is ready to
proceed. At this point a timing routine is activated which computes and records (in milliseconds) the time taken by the subject to respond to each question, the CPU (central processing unit) time associated with administration and calculations for each question, and the total elapsed time.

Next, an analogy question and five possible answers (only one of which is correct) are displayed on the screen and remain there until a response between '0' and '5' is entered on the terminal keyboard. All other responses are rejected and an appropriate message is displayed. A '0' response indicates the answer is not known and is considered an incorrect response to the question.

The response is then evaluated as discussed above under 'classification procedure' (p. 18). All testing data associated with the test item are automatically placed on the subject's file. These include: question identification, item response, correct/incorrect indicator, probability levels for high and low groups, calculated $R_i$ and $A$ scores, $A$ level in effect, total number of items right, total percent right, classification indicator (i.e. high, low, or none), interrupt and operating error counters, total CPU time, total elapsed time, and elapsed item response time.
If classification is not made then the next question is presented and the process is repeated until classification is made. If the subject is classified as belonging to the low group then testing is theoretically terminated. If classified to the high group then the next test is administered following the same procedure as outlined for the first test. When testing is terminated, the date and time are written on the end of the subject's file, a termination message is displayed on the video screen, and the subject is automatically 'signed-off'. Facilities are built into the program to permit the subject to sign himself off in the case of an emergency and to sign on again later, picking up where he left off. Any such action is recorded on his file including place and length of interruption so that the data can be excluded from analysis where desired.

IV DISCUSSION

The CCTT model was intended to serve both demonstration and research purposes and was thus kept rather simple in terms of decision design and types of tests used. Demonstration purposes required that testing be terminated once a subject was classified while the research design required administration of the complete tests in different sequences (see Chapter V, Methodology). For these reasons, the
decision by the computer model to classify a subject prior to test completion was simply recorded on the subject's file and he was allowed to finish the tests, thus providing valuable validation data. This also permitted collection of classification data at a variety of A values. Timing information was recorded to permit relative cost estimates of CCTT but several other uses of this data are also possible (see Chapter VI).
CHAPTER V

APPLICATION OF THE MODEL

I SAMPLE

The sample was comprised of a total of 180 University of British Columbia students from four sections of an undergraduate introductory organizational behavior course. Participation was on a voluntary basis and required approximately two hours of each subject's time, one hour of which was during regularly scheduled classes and the other at the subject's convenience within a given time period. Individual performance data and overall findings were presented to the subjects upon completion of the study and bonus grade points were awarded. Testing was conducted over a seven week period during the fall of 1973.

II METHODOLOGY

Two of the four sections were randomly selected and the paper version of the tests (Appendix A) was administered in class. One section was given the verbal test first, followed by the numerical test. The second section received the same tests in the reverse order. Responses were scored for each test and results for the sections were combined into a 'paper l'st' group.

The median score for the group on the verbal test was then calculated (22/40) and used to divide the group into high and low scoring categories. Next, the responses of the
high category for each verbal test item were examined to determine what proportion answered the item right. This proportion was the equivalent to the probability of a high verbal scorer getting the item right. Similarly, item probabilities were calculated for each verbal item when membership was in the low category.

The same procedure was used to determine item probabilities for high and low categories on the numerical paper test (median = 26/40). These verbal and numerical item probabilities (Table I) were then placed on computer files (Appendix D) for input into the CCTT model as described in the previous chapter.

A period of approximately three weeks was allowed to elapse from when the first two sections had completed the paper version of the tests. Next the computer version of the tests (the CCTT model) was made available to all subjects (four sections) for a period of nine days. During this period each subject was permitted to undergo the computer administration of the tests at his or her convenience using the instructions handed out in class (Appendix C) to get 'signed-on' to the computer. Once 'signed-on', the video screen of the conversational computer terminal provided all necessary instructions for the subject to complete the tests with 'sign-off' being handled automatically by the
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</tr>
<tr>
<td>8</td>
<td>.351</td>
<td>.771</td>
</tr>
<tr>
<td>9</td>
<td>.459</td>
<td>.604</td>
</tr>
<tr>
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<td>.604</td>
</tr>
<tr>
<td>11</td>
<td>.297</td>
<td>.563</td>
</tr>
<tr>
<td>12</td>
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<td>15</td>
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<td>.521</td>
</tr>
<tr>
<td>16</td>
<td>.568</td>
<td>.750</td>
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<tr>
<td>17</td>
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<td>.542</td>
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<td>18</td>
<td>.297</td>
<td>.396</td>
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<td>19</td>
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<td>.896</td>
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<td>20</td>
<td>.622</td>
<td>.792</td>
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<tr>
<td>21</td>
<td>.541</td>
<td>.563</td>
</tr>
<tr>
<td>22</td>
<td>.351</td>
<td>.729</td>
</tr>
<tr>
<td>23</td>
<td>.324</td>
<td>.646</td>
</tr>
<tr>
<td>24</td>
<td>.216</td>
<td>.479</td>
</tr>
<tr>
<td>25</td>
<td>.405</td>
<td>.833</td>
</tr>
<tr>
<td>26</td>
<td>.243</td>
<td>.750</td>
</tr>
<tr>
<td>27</td>
<td>.486</td>
<td>.813</td>
</tr>
<tr>
<td>28</td>
<td>.378</td>
<td>.667</td>
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<tr>
<td>29</td>
<td>.243</td>
<td>.521</td>
</tr>
<tr>
<td>30</td>
<td>.081</td>
<td>.188</td>
</tr>
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<td>31</td>
<td>.703</td>
<td>.875</td>
</tr>
<tr>
<td>32</td>
<td>.568</td>
<td>.792</td>
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<tr>
<td>33</td>
<td>.405</td>
<td>.729</td>
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<td>34</td>
<td>.459</td>
<td>.667</td>
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<tr>
<td>35</td>
<td>.189</td>
<td>.354</td>
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<tr>
<td>36</td>
<td>.216</td>
<td>.563</td>
</tr>
<tr>
<td>37</td>
<td>.784</td>
<td>.875</td>
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<td>38</td>
<td>.703</td>
<td>.833</td>
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<tr>
<td>39</td>
<td>.541</td>
<td>.604</td>
</tr>
<tr>
<td>40</td>
<td>.595</td>
<td>.833</td>
</tr>
</tbody>
</table>

$\phi$ - proportion of subjects in high scoring group who answer test item $i$ correctly  

$P_i$ - proportion of subjects in low scoring group who answer test item $i$ correctly
computer. Details of how the CCTT model administered and scored the tests were provided in the previous chapter under 'design' (p. 18).

The model was artificially limited to a maximum of six subjects at any one time to avoid tying up too many conversational terminals for one project. An abandoned terminal automatically 'signs-off' after a short inactive period. Random visits were made (by this researcher) to the terminal area to check for collaboration of subjects and to provide assistance if any difficulties were being encountered in terminal operation. Neither were observed.

For those subjects that had already completed the paper version of the tests, the CCTT model administered the two tests in the opposite order. That is, those subjects that did the verbal test first on the paper version of the tests were given the numerical test first by the computer. This also resulted in a different sample question being presented as only one sample question (either verbal or numerical) was presented for a complete testing.

Once the computer phase of testing was complete, another three weeks were allowed to elapse. Then, the paper version of the tests was administered in class to the two sections that had only completed the computer version. Again the order of tests was reversed from that of the previous administration.
III RESULTS AND INTERPRETATION

Test order

Administration of the verbal and numerical forms of the analogy test was counterbalanced to offset any ordering effects. Table II indicates that for the verbal test there was no significant difference in verbal scores whether this test came before or after the numerical test. This applied to both the paper and computer administration of the tests. For the numerical test however, order of administration did have a significant effect which was in opposing directions for paper and computer administrations. With paper administration the numerical score was significantly higher when the numerical test followed the verbal test. With computer administration however, numerical performance declined significantly when the numerical test followed the verbal test. The reasons for these observed differences are not clear.

Learning effects

A period of approximately three weeks was left between the first paper administration of the tests and the computer administration, and another three weeks between this and the second paper administration so as to minimize any learning effects. Nevertheless, significant learning effects
### TABLE II

**COMPARISON OF TESTING ORDER SCORES-
CCTT AND PAPER TESTING**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Test</th>
<th>Administration</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>T Test Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper 1'st</td>
<td>45</td>
<td>V</td>
<td>V/N</td>
<td>22.222</td>
<td>5.464</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>N</td>
<td>N/V</td>
<td>23.625</td>
<td>5.182</td>
<td>1.200</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>N</td>
<td>V/N</td>
<td>25.689</td>
<td>2.891</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>N</td>
<td>N/V</td>
<td>23.225</td>
<td>4.938</td>
<td>2.729 xxx</td>
</tr>
<tr>
<td>CCTT 1'st</td>
<td>26</td>
<td>V</td>
<td>V/N</td>
<td>22.885</td>
<td>4.918</td>
<td></td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>N</td>
<td>N/V</td>
<td>23.938</td>
<td>5.825</td>
<td>0.733</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>N</td>
<td>V/N</td>
<td>21.783</td>
<td>6.082</td>
<td></td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>N</td>
<td>N/V</td>
<td>25.879</td>
<td>3.577</td>
<td>2.839 xxx</td>
</tr>
</tbody>
</table>

N = Numerical  
V = Verbal  

**Significance level (2 tail)**  
x = .1  
xx = .05  
xxx = .01
did occur on overall test scores (see Table III). For those subjects completing the paper administration first, there was a significant learning effect on the verbal test and a positive though not significant learning effect on the numerical test. For those completing the computer administration first there were significant learning effects on both the verbal and numerical tests with the numerical learning effect being the stronger.

Significant learning effects were also evident in overall test times (see Table IV). Those subjects completing the paper tests first took significantly less time on the computer version of both the verbal and numerical tests than did the computer first group. Similarly, those completing the computer tests first took significantly less time on the paper versions of the verbal and numerical tests than did the paper first group.

Test administration

Scores. No significant differences were observed in overall test scores between the paper first and computer first administrations of either the verbal or numerical tests (see Table III). This would tend to indicate that the two methods of test administration, paper and computer, are comparable.
### TABLE III

**COMPARISON OF TEST SCORES - CCTT AND PAPER TESTING**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Test</th>
<th>Administration</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>T Test Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper 1'st</td>
<td>69</td>
<td>V</td>
<td>CCTT</td>
<td>25.725</td>
<td>5.377</td>
<td>2.756 xxx</td>
</tr>
<tr>
<td>Paper 1'st</td>
<td>69</td>
<td>N</td>
<td>CCTT</td>
<td>26.058</td>
<td>2.950</td>
<td>1.361</td>
</tr>
<tr>
<td>Paper 1'st</td>
<td>48</td>
<td>V</td>
<td>CCTT</td>
<td>23.417</td>
<td>5.222</td>
<td>1.943 x</td>
</tr>
<tr>
<td>Paper 1'st</td>
<td>48</td>
<td>N</td>
<td>CCTT</td>
<td>23.896</td>
<td>5.203</td>
<td>2.763 xxx</td>
</tr>
<tr>
<td>Paper 1'st</td>
<td>85</td>
<td>V</td>
<td>Paper</td>
<td>22.882</td>
<td>5.348</td>
<td></td>
</tr>
<tr>
<td>Paper 1'st</td>
<td>67</td>
<td>V</td>
<td>CCTT</td>
<td>23.896</td>
<td>5.240</td>
<td>1.166</td>
</tr>
<tr>
<td>Paper 1'st</td>
<td>85</td>
<td>N</td>
<td>Paper</td>
<td>24.529</td>
<td>4.151</td>
<td>-0.251</td>
</tr>
<tr>
<td>Paper 1'st</td>
<td>63</td>
<td>N</td>
<td>CCTT</td>
<td>24.333</td>
<td>5.016</td>
<td></td>
</tr>
</tbody>
</table>

N= Numerical
V= Verbal

Significance level (2 tail)
x = .1
xx = .05
xxx = .01
TABLE IV

COMPARISON OF TEST TIMES—
CCTT AND PAPER TESTING

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Test Administra-</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>T Test Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper 1st</td>
<td>70</td>
<td>V</td>
<td>CCTT</td>
<td>762.228</td>
<td>172.698</td>
</tr>
<tr>
<td>CCTT 1st</td>
<td>60</td>
<td></td>
<td></td>
<td>920.089</td>
<td>312.669</td>
</tr>
<tr>
<td>Paper 1st</td>
<td>70</td>
<td>N</td>
<td>CCTT</td>
<td>062.058</td>
<td>311.601</td>
</tr>
<tr>
<td>CCTT 1st</td>
<td>60</td>
<td></td>
<td></td>
<td>1586.636</td>
<td>665.179</td>
</tr>
<tr>
<td>Paper 1st</td>
<td>37</td>
<td>V</td>
<td>Paper</td>
<td>763.800</td>
<td>155.340</td>
</tr>
<tr>
<td>CCTT 1st</td>
<td>68</td>
<td></td>
<td></td>
<td>633.540</td>
<td>158.040</td>
</tr>
<tr>
<td>Paper 1st</td>
<td>37</td>
<td>N</td>
<td>Paper</td>
<td>1201.620</td>
<td>284.760</td>
</tr>
<tr>
<td>CCTT 1st</td>
<td>68</td>
<td></td>
<td></td>
<td>990.900</td>
<td>244.980</td>
</tr>
<tr>
<td>Paper 1st</td>
<td>37</td>
<td>V</td>
<td>Paper</td>
<td>763.800</td>
<td>155.340</td>
</tr>
<tr>
<td>CCTT 1st</td>
<td>60</td>
<td></td>
<td></td>
<td>920.089</td>
<td>312.669</td>
</tr>
<tr>
<td>Paper 1st</td>
<td>37</td>
<td>N</td>
<td>Paper</td>
<td>1201.620</td>
<td>284.760</td>
</tr>
<tr>
<td>CCTT 1st</td>
<td>60</td>
<td></td>
<td></td>
<td>1586.636</td>
<td>665.179</td>
</tr>
</tbody>
</table>

N= Numerical
V= Verbal

Significance level (2 tail)
x = .1
xx = .05
xxx = .01
xxxx = .001
**Times.** For complete tests, computer administration was significantly slower than paper administration for both verbal and numerical testing (see Table IV). That is, on an item for item comparison, subjects took longer on the computer administration with an average time per verbal item of 23.0 seconds compared with 19.1 for paper administration and 39.7 seconds per numerical item compared with 30.0 seconds for paper. Some of this difference may be explained by the slightly different instructions regarding times for each test administration (see Appendices A, D). It is also likely that subjects did not experience the same pressure in CCTT as they did in the group test administration where their completion time was observable by their classmates.

The mean time to classify a subject using CCTT was substantially less (V = 205 sec., N = 478 sec., Table V) than to completely test a subject using paper administration (V = 764 sec., N = 1202 sec., Table IV). This demonstrates that significant time savings may be realized in using a sequential CCTT model for classification with this type of test. (Total time saving = 65%, V = 73%, N = 60%).

**Items.** The number of items on the paper administration of the verbal and numerical tests was forty each (Appendix A). Subjects were classified by CCTT after an average of 9.0 verbal items and 9.9 numerical items (Table V).
### TABLE V

**TIME AND NUMBER OF ITEMS REQUIRED FOR CCTT TO CLASSIFY SUBJECTS (A LEVEL = 1.39)**

<table>
<thead>
<tr>
<th>Elapsed Time (sec)</th>
<th>CCTT 1st (N=60)</th>
<th>Paper testing 1st (N=70)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Verbal</td>
<td>Numerical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Verbal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Numerical</td>
</tr>
<tr>
<td>Elapsed Time (sec)</td>
<td>mean</td>
<td>205.3</td>
</tr>
<tr>
<td></td>
<td>std. dev.</td>
<td>161.2</td>
</tr>
<tr>
<td></td>
<td>minimum</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>maximum</td>
<td>837</td>
</tr>
<tr>
<td></td>
<td>per item</td>
<td>22.8</td>
</tr>
</tbody>
</table>

| CPU Time (sec)    | 1.101           | 1.200                  |
|                   | 1.151           | 1.359                  |

| Items             | mean            | 9.0                    | 9.9                    |
|                   | std. dev.       | 5.3                    | 7.1                    |
|                   | minimum         | 4                      | 3                      |
|                   | maximum         | 23                     | 38                     |

|                   |                 | 27                     |
|                   |                 | 35                     |
This represents an average reduction of more than 75% in the number of test items required using CCTT.

**Accuracy.** With the substantial reduction in number of test items required, CCTT was still able to classify subjects on the numerical test with an accuracy of 81.0% and on the verbal test with an accuracy of 85.1% (Table VI).

**Costs.** Although several simplifying assumptions were made it would appear that CCTT costs would be competitive with paper testing (Appendix G). In the example presented, actual CCTT costs were computed to be $0.730 per subject compared with hypothetical costs of $0.675 per subject using paper testing, a difference of 8%.

**Anxiety.** Although not specifically part of the study design, reaction to CCTT was informally discussed with each of the four test groups in post-test analysis sessions. Reaction was for the most part favorable to CCTT. Many indicated enjoyment of the novelty of CCTT and others indicated they felt much less tense than in the group paper administration. Several noted frustration at not being able to change answers on the terminal. Only three subjects expressed objections to the concept of CCTT and two of these individuals were also against any form of psychological measurement. All subjects were in favour of the convenient demand testing feature.
### TABLE VI

CCTT SUBJECT CLASSIFICATION TABLES  
(A LEVEL = 1.39)

<table>
<thead>
<tr>
<th>Numerical Test</th>
<th>Classified</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>30</td>
<td>2</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>10</td>
<td>21</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>23</td>
<td>63</td>
<td></td>
</tr>
</tbody>
</table>

Accuracy = 81.0%

<table>
<thead>
<tr>
<th>Verbal Test</th>
<th>Classified</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>39</td>
<td>8</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>2</td>
<td>18</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
<td>26</td>
<td>67</td>
<td></td>
</tr>
</tbody>
</table>

Accuracy = 85.1%
Advantages

- CCTT appears ideally suited to multi-stage and tailored testing.
- CCTT facilitates the application of statistically complex decision and testing models such as the probability sequential model presented here which cannot be applied in a conventional testing environment.
- CCTT offers the convenience of demand, twenty-four hour testing to both examiner and examinee.
- CCTT is self-instructional and eliminates the need for a formal test administrator.
- CCTT is capable of standardized test instruction.
- CCTT can significantly reduce testing time and the number of test items required.
- CCTT permits adjustment of testing accuracy level desired.
- CCTT automatically, instantaneously and objectively scores, records, and interprets test results, providing immediate feedback capabilities without the
intervention of a psychologist.

-CCTT is capable of accurate latency response recording.

-CCTT data collection provides a broad, highly accessible data base for further research and analysis.

-CCTT is capable of collecting self-validation data.

-CCTT does not appear to affect overall test scores.

-CCTT does appear to be relatively cost competitive with conventional testing.

-CCTT does not appear to generate undue anxiety.

-CCTT is portable using a suitcase type terminal that operates over any conventional telephone.

-CCTT is probably applicable to many other forms of testing.

**Disadvantages**

-CCTT may not be readily applicable to certain forms of testing, such as those requiring pictorial representation.

-CCTT may be relatively expensive for some forms of testing, such as those requiring administration of the entire test.

-CCTT presently requires considerable development and testing.

-CCTT is dependent upon a reliable computer system which is not prone to frequent or prolonged failures.
-CCTT may adversely affect the performance of some individuals such as those who feel threatened by a computer.

II LIMITATIONS

Only one CCTT model was developed. Its emphasis was categorization of subjects rather than continuous measurement and it predicted test performance rather than task (job) performance. Reactions and anxieties of subjects between the two modes of testing were not specifically studied. Formal and detailed cost comparisons of the two methods of testing were not attempted.

III CONCLUSIONS

From the present investigation it is concluded that:
- Various psychological tests may be administered via conversational computer terminals.
- A variety of CCTT models are possible.
- A sequential probability CCTT model will significantly shorten testing time.
- CCTT is self-administering.
- CCTT appears cost-competitive with conventional testing.
IV SUGGESTIONS FOR FURTHER RESEARCH

Further research of the CCTT concept is suggested in seven main areas; the present model, other models, tests, criteria, anxiety, costs, and applications.

With regard to the present model it is likely that the number of items required for classification may be substantially reduced by arranging test items so that maximum discriminators are encountered early in the test. Such a procedure would most likely require collection of a further calibration sample to determine if item ordering had any significant effect on responses.

Additional, more complex models such as those discussed in Chapter III should be examined. Two types of branching multi-stage models particularly warrant investigation. One is a model that will determine which tests should be administered. This would likely operate on the basis of pre-defined decision rules for ranges of scores on tests such as those measuring abilities. A more complex version of this model would deal with tests in areas such as personality measurement. The second branching multi-stage model is one which would branch to test items of appropriate difficulty levels for the subject. This again could shorten tests, providing more finite measurement at the appropriate level. Another type of model requiring more specific, problem-oriented research is the complexity/
branching model described in Chapter III. It is comprised of many possible segments, each of which may be researched on its own. Further, it may have to be developed for specific applications which are perhaps unique to a given environment.

Other forms and types of tests should also be attempted using CCTT, including various response modes. Alternative methods of response input should be researched for tests that do not lend themselves to multiple choice answers. Possible conversion of tests to convenient input formats such as 'multiple choice' should also be considered. Various methods of test presentation should be explored for tests that involve non-verbal items such as pictorial representations.

CCTT should be applied to the prediction of actual performance criteria as well as known test scores. The present testing model was used to predict actual test scores when in fact tests are typically designed to predict certain performance criteria. This represents a more difficult application of the model as test validity becomes a determining factor in its effectiveness.

Formal measurement of objections to CCTT and resultant anxiety levels should be studied. It appears reasonable to assume that some individuals may either object to CCTT or experience a change in anxiety level while undergoing CCTT. The nature and extent of these should be determined. For
example, they may be found to exist but not adversely affect test performance or may only exist within certain groups of individuals under certain circumstances.

Comparative cost data should be collected in the actual application of CCTT in an appropriate environment. The present study was limited to hypothetical paper testing costs, and comparisons were on the basis of a short testing period in an experimental environment.

Additional applications and expansion of the CCTT concept such as outlined in Chapter I should be explored more fully. Specifically, this entails expansion of the CCTT concept to interview, select, and ultimately place applicants.
V SUMMARY

CCTT has been demonstrated to be a viable substitute for at least one form of psychological testing. As such it will eliminate two timely delays in the personnel selection process as described in Chapter one, namely awaiting test administration and test interpretation while at the same time providing numerous other advantages. It has the added advantage of being capable of substantially reducing testing time. Moreover the CCTT concept appears expandable to the entire selection process thus solving further time delay and objectivity problems. Further research, preferably in an organizational setting will be required to explore this and other questions raised.

With the costs of computer facilities constantly declining, hardware becoming more sophisticated, and complete computer systems available to the small user on a time sharing basis, it appears highly probable that CCTT will eventually replace conventional psychological testing.
BIBLIOGRAPHY


Lord, F. M. A theoretical study of two-stage testing. Psychometrika, Vol. 36, No. 3, September 1971. (a)


Slosson, R. L. The Slosson Intelligence Test for Children and Adults. East Aurora, Ill.: Slosson Educational Publication, 1963.


APPENDICES
APPENDIX A

Materials Used in Paper Test Administration
Shortened Verbal Form

Minnesota Multimodal Analogy Test

1971 Revision
INSTRUCTIONS

On the following pages are some analogy questions we would like you to answer. This test has been designed to take approximately 35 minutes to complete, and you will have to work quickly to finish in the time allowed.

The questions are arranged in two groups. The first 40 questions are in word form; the last 40 questions are in the form of numbers. Here is an example of a word analogy:

Feather : _________ :: Scale : Fish

(1) Swim  (2) Air  (3) Water  (4) Bird  (5) Fly

This is the way it should read: "Feather is to blank as Scale is to Fish?"
You are to choose the word which best completes the analogy. In this example, you might reason that a scale grows on a fish - what does a feather grow on? Look at the five possible answers. "Bird" is the best answer, so you would write "4" in the correct space on the answer sheet. The procedure for answering the number analogies is the same.

You will find that the reasoning required for each analogy question is different, and that the blank may appear in any position. For each question you must determine the most appropriate reasoning and then select the word which best completes the analogy.

For each analogy question, write the number of the correct answer on the answer sheet. If you are not sure which is the correct answer, write the figure "0" in the space provided on the answer sheet and go on to the next question. Please work in pen, and do not change any answers. Do not make any marks on the test booklet itself.

Be careful to put the answer in the right space.

Please answer every question. Begin with the word analogies and continue through the number analogies until you have answered all 80 questions. Be careful that you do not skip any questions.

Please record the times where indicated on the answer sheet and turn in all test materials as soon as you have finished.

If you have any questions, please ask the person in charge.

Please be assured that your responses will be kept in strictest confidence.
WORD ANALOGIES

1. _________ : Hunter :: Doctor : Lawyer
   (1) Engineer  (2) Gentleman  (3) Drunk  (4) Fisherman  (5) Citizen
2. Dive : Swim :: Dove : _________
   (1) Tree  (2) Coo  (3) Fly  (4) Swim  (5) Swimming
3. _________ : Clown :: Tall : Dwarf
   (1) Short  (2) Laugh  (3) Dull  (4) Beard  (5) Circus
4. _________ : Bacon :: Breast : Ham
   (1) Steak  (2) Pig  (3) Baby  (4) Eggs  (5) Wing
5. _________ : Miss :: Husband : Mr.
   (1) Housewife  (2) Lady  (3) Nurse  (4) Lass  (5) Queen
6. Dull : _________ :: Shiny : Sharp
   (1) Dumb  (2) Keen  (3) Bright  (4) Boring  (5) Dull
7. Check : _________ :: Cash : Money
   (1) Mark  (2) Gold  (3) Note  (4) Giant  (5) Goose
8. Tree : Man :: Sap : _________
   (1) Axe  (2) Woman  (3) Maple  (4) Blood  (5) Arm
9. Pick : Violin :: _________ : Banjo
   (1) Play  (2) Sing  (3) Bow  (4) String  (5) Fiddle
10. _________ : Behind :: Drag : Ahead
    (1) Before  (2) Beside  (3) After  (4) Pull  (5) Push
11. Gasoline : Car :: _________ : Clock
(1) Oil (2) Wind (3) Spring (4) Stem (5) Gear

12. Walk : Stand :: Mow :: _________
(1) Climb (2) Shave (3) Grow (4) Run (5) Lawn

13. _________ : Canoe :: Cannon : Pistol
(1) Battleship (2) Rowboat (3) Rifle (4) Ocean (5) Oar

14. Sin : Song :: Son :: _________
(1) Chorus (2) Single (3) Hum (4) Sing (5) Daughter

15. Marble : _________ :: Earth : Sun
(1) Fire (2) Bright (3) Round (4) Basketball (5) Game

16. Ton : _________ :: Tin : Tinkle
(1) Pound (2) Tongue (3) Tonight (4) Wet (5) Steel

17. _________ : College :: Pray : Church
(1) Books (2) Teacher (3) Learn (4) Class (5) Study

18. Ash : Beech :: Oak :: _________
(1) Pine (2) Maple (3) Walnut (4) Hickory (5) Elm

19. Train : Auto :: Track :: _________
(1) Tie (2) Tire (3) Car (4) Road (5) Path

20. _________ : Yesterday :: Tomorrow :: Today
(1) Tomorrow (2) Tonight (3) Today (4) Now (5) Then
21. Unkind : Sweetheart :: __________ : Guard
   (1) Careless (2) Cruel (3) Safe (4) Royal (5) Happy

22. Hire : Cent :: __________ : Scent
   (1) Fire (2) Smell (3) Dent (4) Work (5) Higher

23. Tomato : __________ :: Carrot : Orange
   (1) Beet (2) Celery (3) Peach (4) Potato (5) Pear

24. __________ : Faith :: Valuable : Trust
   (1) Believe (2) Honor (3) Sure (4) Heaven (5) Dear

25. Gobble : Person :: __________ : Turkey
   (1) Talk (2) Thanksgiving (3) November (4) Eat (5) Feed

26. Acorn : __________ :: Colt : Horse
   (1) Nut (2) Mare (3) Seed (4) Oak (5) Saddle

27. Deer : Does :: Cattle : __________
   (1) Did (2) Horses (3) Calf (4) Doesn't (5) Cows

28. Blue : __________ :: Yellow : Orange
   (1) Purple (2) Red (3) Green (4) Brown (5) Gold

29. Dog : __________ :: Music : Hymn
   (1) Bark (2) Hound (3) Church (4) Howl (5) Cat

30. Dot : Circle :: Marble : __________
   (1) Ball (2) Tire (3) Square (4) Cigarette (5) Glass
31. School : Fish :: ________ : Tree
(1) College (2) Turtle (3) Plant (4) Grove (5) Book

32. Odd : Proper :: Queer : ________
(1) Correct (2) Reason (3) Ideal (4) Wise (5) Wrong

33. Who'd : Would :: We've : ________
(1) Went (2) Have (3) Will (4) They (5) Wouldn't

34. Cloth : ________ :: Animal : Elephant
(1) Shirt (2) Leather (3) Sail (4) Linen (5) Fashion

35. Nail : Screw :: ________ : Nut
(1) Tack (2) Clip (3) Bolt (4) Washer (5) Hammer

36. Sea : Wave :: ________ : Brook
(1) Water (2) Ocean (3) Swell (4) River (5) Creek

37. Prune : Grape :: ________ : Plum
(1) Orange (2) Raisin (3) Wine (4) Fruit (5) Grapefruit

38. Eager : ________ :: Honor : Shame
(1) Lively (2) Hurt (3) Pity (4) Dull (5) Spirit

39. Bold : Honest :: ________ : Unfair
(1) Forward (2) Unkind (3) Shy (4) Gentle (5) Trust

40. Pot : ________ :: Pool : Loop
(1) Round (2) Pan (3) Rope (4) Top (5) Pond
Shortened Numerical Form

Minnesota Multimodal Analogy Test

1971 Revision
INSTRUCTIONS

On the following pages are some analogy questions we would like you to answer. This test has been designed to take approximately 35 minutes to complete, and you will have to work quickly to finish in the time allowed.

The questions are arranged in two groups. The first 40 questions are in number form; the last 40 questions are in word form. Here is an example of a number analogy:

\[ 746 : 4 :: 839 : \_ \_ \_ \_ \_ \]

(1) 9 (2) 4 (3) 76 (4) 8 (5) 3

This is the way it should read: "First number is to Second number as Third number is to blank." You are to choose the number which best completes the analogy. In this example, you might reason that the number "4" is in the middle of number 746. What number is in the middle of 839? Look at the five possible answers. Since the number "3" is in the middle of 839, you would write "5" in the correct space on the answer sheet. The procedure for answering the word analogies is the same.

You will find that the reasoning required for each analogy question is different, and that the blank may appear in any position. For each question you must determine the most appropriate reasoning and then select the word which best completes the analogy.

For each analogy question, write the number of the correct answer on the answer sheet. If you are not sure which is the correct answer, write the figure "0" in the space provided on the answer sheet and go on to the next question. Please work in pen, and do not change any answers. Do not make any marks on the test booklet itself.

Be careful to put the answer in the right space.

Please answer every question. Begin with the number analogies and continue through the word analogies until you have answered all 80 questions. Be careful that you do not skip any questions.

Please record the times where indicated on the answer sheet and turn in all test materials as soon as you have finished.

If you have any questions, please ask the person in charge.

Please be assured that your responses will be kept in strictest confidence.
NUMBER ANALOGIES

1. 2 : 6 :: __________ : 17
   (1) 11 (2) 3 (3) 28 (4) 9 (5) 42

2. 6 : __________ :: 14 : 8143
   (1) 93 (2) 108 (3) 4137 (4) 7 (5) 163

3. __________ : 8 :: 37 : 16
   (1) 4 (2) 13 (3) 26 (4) 419 (5) 3

4. __________ : 827 :: 3 : 1963
   (1) 7 (2) 28 (3) 2 (4) 8 (5) 14

5. 23 : 67 :: 13 : __________
   (1) 45 (2) 78 (3) 46 (4) 34 (5) 56

6. __________ : 3147 :: 6 : 367
   (1) 17 (2) 34 (3) 31 (4) 14 (5) 7

7. 12 : __________ :: 456 : 345
   (1) 431 (2) 13 (3) 64 (4) 235 (5) 67

8. 405060 : 7 :: 314151 : __________
   (1) 2 (2) 1 (3) 5 (4) 6 (5) 7

9. 4 : 1411 : __________ : 2223
   (1) 2 (2) 3 (3) 4 (4) 23 (5) 1

10. 1345 : 2 :: 5679 : __________
    (1) 2 (2) 8 (3) 5 (4) 7 (5) 3
11. \[ \frac{2478}{4} = 1354 \]
   (1) 7 (2) 4 (3) 2 (4) 32 (5) 78

12. \[ \frac{4120}{7} = 590 \]
   (1) 2 (2) 24 (3) 12 (4) 1 (5) 4

13. \[ \frac{3246}{3} = 1079 \]
   (1) 4 (2) 1 (3) 3 (4) 6 (5) 2

14. \[ 3, 7, 11 \div 13, 17, 21 = 15, 19, 23 \]
   (1) 7, 9, 11 (2) 1, 3, 5 (3) 2, 6, 10 (4) 7, 11, 15 (5) 1, 5, 9

15. \[ 1 + 1 = 1 \times 1 \div 3 \times 3 \]
   (1) 18 (2) 6 (3) 2 + 2 (4) (3 - 3 (5) 9

16. \[ 192837 : 4 \div 283746 \]
   (1) 4 (2) 6 (3) 9 (4) 8 (5) 5

17. \[ \frac{1}{2}, \frac{1}{4}, \frac{1}{8} \div 16, 8, 4 = 2, 4, 8 \]
   (1) 1/3, 1/6, 1/12 (2) 0, 2, 4 (3) 2/4, 2/8, 2/16 (4) 1/16, 1/32, 1/64 (5) 1/2, 1, 2

18. \[ 7 \times 3 = 4 - 1 \div (6/3 - 1) \]
   (1) (7/3) - 1 (2) 21 (3) 7 - 4 (4) 4 + 3 (5) (9/3) - 1

19. \[ 2 + 2 \div 1 - 1 = 2 - 2 \]
   (1) 3 + 3 (2) 2 \times 2 (3) 1 \times 1 (4) 1 + 1 (5) 4 + 4

20. \[ 7717 : \frac{6466}{4} \]
   (1) 8 (2) 1 (3) 7 (4) 6 (5) 5
21. \[ \frac{789}{2} \equiv \frac{34}{1} \]
   (1) 4  (2) 23  (3) 78  (4) 6  (5) 5

22. \[ \frac{13}{24} \equiv \frac{24}{21} \]
   (1) 47  (2) 15  (3) 35  (4) 15  (5) 36

23. \[ \frac{283}{46} \equiv \frac{12}{23} \]
   (1) 43  (2) 729  (3) 61  (4) 25  (4) 3818

24. \[ \frac{525}{718} \equiv \frac{26}{525} \]
   (1) 191  (2) 8  (3) 3  (4) 7438  (5) 25

25. \[ \frac{1792}{3383} \equiv \frac{9}{1792} \]
   (1) 1686  (2) 491  (3) 37  (4) 9  (5) 5566

26. \[ \frac{0}{3} \equiv \frac{3}{0} \]
   (1) 30  (2) 7  (3) 10  (4) 10 - 3  (5) .3

27. \[ \frac{414}{629} \equiv \frac{2}{414} \]
   (1) 4  (2) 1  (3) 2  (4) 14  (5) 3

28. \[ \frac{21}{9} \equiv \frac{14}{21} \]
   (1) 7  (2) 8  (3) 9  (4) 5  (5) 3

29. \[ \frac{32}{12} \equiv \frac{23}{32} \]
   (1) 63  (2) 21  (3) 13  (4) 22  (5) 32

30. \[ \frac{4197}{7149} \equiv \frac{91}{4197} \]
   (1) 9247  (2) 19  (3) 29  (4) 49  (5) 74
31. \[ \frac{36}{198} : \frac{104}{6983} : 6 :: 98 : 3 \]
   (1) 7 (2) 36 (3) 198 (4) 104 (5) 6983

32. \[ \frac{814}{27} : \frac{418}{814} : 27 :: \frac{724}{278} : \frac{72}{724} : 72 \]
   (1) 724 (2) 278 (3) 72 (4) 87 (5) 74

33. \[ \frac{431}{134} : \frac{91}{19} : \frac{278}{27} \]
   (1) 19 (2) 90 (3) 910 (4) 119 (5) 09

34. \[ \frac{74}{87} : \frac{910}{119} : \frac{19}{90} : \frac{91}{431} : 7 :: 724 : \frac{27}{91} \]
   (1) 27 (2) 924 (3) 4 (4) 142 (5) 782

35. \[ \frac{8 + 0}{8 + 1} : \frac{8 \times 0}{8 \times 1} : \frac{471}{27} \]
   (1) 8 \times 1 (2) 1 (3) 9 (4) 9 \times 0 (5) 1 \times 0

36. \[ \frac{717}{146} : \frac{641}{171} : \frac{177}{171} : \frac{717}{614} : 717 :: 7 \]
   (1) 171 (2) 614 (3) 177 (4) 717 (5) 617

37. \[ \frac{876}{234} : \frac{987}{234} : \frac{717}{171} :: 8 \times 1 \]
   (1) 769 (2) 454 (3) 345 (4) 235 (5) 793

38. \[ \frac{575}{75} : \frac{557}{755} :: 28 : 82 \]
   (1) 755 (2) 577 (3) 757 (4) 575 (5) 75

39. \[ \frac{2 \times 2}{6 - 1} : \frac{1}{2} :: 6 - 1 : \frac{2 \times 2}{2} :: 2 \times 2 \]
   (1) 12 - 2 (2) 5 (3) 5 + 3 (4) 6 - 2 (5) 8 + 1

40. \[ \frac{689}{1345} : \frac{2}{1345} :: 689 \]
   (1) 5 (2) 8 (3) 4 (4) 7 (5) 1
Answer Sheet for Paper Tests
| NAME (PLEASE PRINT) | .......................................................... |
| I.D. NUMBER | SECTION | AGE | SEX |

enter time: 

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APPENDIX B

Fortran IV CCTT Model
LOGICAL ATN
CALL ATNTRP(ATN)
DIMENSION Q(25), AL(20), IT(5), A(25), PH(40), PL(40)
INTEGER GR(26)
REAL AV(4)/1.39, 2.30, 3.00, 4.61/
INTEGER*2 ANS(40), RON, RON/R*, S*/S*, S0*/0*, S6*/6*/
INTEGER*2 NS, NUM, S7/*7*/, S8*/8*/, S9*/9*/, S5*/5*/
C ### SET ERROR COUNTERS AND TEST INDICATORS
REAL*8 SN
NE=0
NES=0
NI=0
NL=2
NQ=0
NEND=0
NM=5
NH=20
NT=8
LG=0
C ### STACK ANY ATTENTION INTERRUPTS
CALL ATNTRP(ATN)
LL=0
NPW=0
C ### DETERMINE TIME OF DAY AND DATE
CALL TIME(6,0, IT)
GO TO 98
99 NI=NI+1
WRITE (NR,96) NI, IC, GR, RON
96 FORMAT (' INTERCEPT', 216, I30, 5X, A1)
IF (NI.GE.NM) GO TO 999
IF (NI.EQ.NL) WRITE (6,104)
C ### DETERMINE TESTING ORDER BY SECTION NUMBER
IF ((NS.EQ.RON) OR (NS.EQ.RON)) NQ=2
IF ((NS.EQ.S7) OR (NS.EQ.S5)) NQ=1
IF (NPW.GE.NL) GO TO 77
IF (NPW.GE.NL) GO TO 1003
1001 IF (NS.EQ.SS) STOP 22
C ### DETERMINE TESTING ORDER BY SECTION NUMBER
IF ((NS.EQ.S7) OR (NS.EQ.S5)) NQ=2
IF ((NS.EQ.S9) OR (NS.EQ.S6) OR (NS.EQ.S8)) NQ=1
IF (NPW.GE.NL) GO TO 77
IF (NPW.GE.NL) GO TO 999
77 WRITE (6,74)
74 FORMAT (' PLEASE ENTER YOUR STUDENT NUMBER (SEVEN DIGITS)')
C ### SAVE INPUT RECORD FOR REREAD
76 CALL SETSTA(5,2)
READ (5,75) SN
75 FORMAT (A8)
READ (5,811) KF

811 FORMAT (17)

C ### CHECK FOR FILE EXISTANCE & PREVIOUS TESTING
610 CALL CHKFL(SN,'8',SN,'804)
CALL SETLIO('8',SN,'804)
CALL GETLST(NT,LST)
FIND (NT,LST)
CALL SETSTA(NT,2)
READ (NT,3322,END=876) I3

3322 FORMAT (1X,I1).
IF(I3.NE.3) GO TO 807

3324 READ (NT,3323,END=877) I,J,LL, LG, NQ, T, RR

3323 FORMAT (34X,5I5,2F12.6)
CALL CLOSFL('8')
CALL TIME(6,0,IT)
WRITE (NT,603) NS,SN,IT
NLJ=36000
FIND (NQ'NLJ)
READ (NQ,15,END=88) ANS,PH,PL

3397 FORMAT (' QUESTIONS WILL CONTINUE FROM SIGNOFF POINT*')
WRITE (6,3397)
NLJ=(2*I+1)*1000+38000
FIND (NQ'NLJ)
GO TO 101

807 WRITE (6,806)
806 FORMAT (' RECORDS INDICATE YOU HAVE DONE THIS PHASE - IF NOT, CALL RON*')
GO TO 999

809 FIND (3'KF)
READ (3,21,END=1001) NUM

21 FORMAT (1X,A1)
IF (NUM.EQ.NS) GO TO 345

322 IF (NES.GE.NL) GO TO 999
WRITE (6,346)

346 FORMAT (' YOUR SECTION NUMBER DOES NOT APPEAR CORRECT - PLEASE REENTER*')
NES=NES+1
READ (5,5) NS
IF (NUM.NE.NS) GO TO 322

C ### CREATE SUBJECT FILE
345 CALL CREATE(SN,1,0,0,'804','808','808','808','808','808','808','808')
CALL CLOSFL('8')
810 CALL SETLIO('8',SN,'804)
887 WRITE (NT,603) NS,SN,IT

603 FORMAT (1X,A1,A8,3X,2A4,1X,3A4)
IF (LG.EQ.1) GO TO 1011
GO TO 618
3 WRITE (6,72)
72 FORMAT (' RESPONSE IS INVALID - PLEASE TRY AGAIN' )
NE=NE+1
IF (NE.GT.NL) GO TO 999
IF (NQ.EQ.0) GO TO 6

79 GO TO 76

C ### DISPLAY TEST INSTRUCTIONS
618 DO 658 IL=1,35
READ (NQ,661) AL

661 FORMAT (20A4)
WRITE (6,662) AL

662 FORMAT (1X,20A4)
IF (IL.EQ.17) READ (5,17) RES

658 CONTINUE
READ (5,17) RES
T=0.

**LOAD TEST ANSWERS AND PROBABILITIES**

READ (NQ,15,END=88) ANS,PH,PL

FORMAT (40A1,4(/,20F4.3))

J=1
RR=0.
I=1

READ (NQ,80,END=88) Q,A

FORMAT (3X,25A4,/,3X,25A4)

**DISPLAY QUESTION AND POSSIBLE ANSWERS**

WRITE (6,82) Q,A

CALL TIME(0)
IT2=0
NE=0

**READ SUBJECT'S RESPONSE**

READ (5,17) RES

FORMAT (A1)

CALL TIME(3,0,IT)
IT3=IT(2)-IT2
IT2=IT(2)

IF (RES.EQ.55) GO TO 3333
IF ((RES.GE.50).AND.(RES.LT.56)) GO TO 20

NE=NE+1
IF (NE.GT.NH) GO TO 999
WRITE (6,19)

FORMAT ('YOUR RESPONSE WAS NOT A NUMBER BETWEEN 0 AND 5 - TRY AGAIN'/)
WRITE (6,82) Q,A
GO TO 16

READ (NQ,80,END=89) Q,A
WRITE (6,82) Q,A

**CALCULATE CLASSIFICATION INFORMATION**

IF (RES.EQ.ANS(I)) GO TO 30
R=PH(I)/PL(I)
RR=RR+1.
NRW=100.

T=T + ALOG(R)
RI=I
PR=RR/RI
IF (T.GT.AV(J)) GO TO 40
B=-1.*AV(J)
IF (T.LT.B) GO TO 50
IF (I.LE.40) GO TO 69
IF (T.GE.O.) GO TO 40
IF (T.LT.O.) GO TO 50
LL=9
GO TO 69

C ### RECORD ITEM TESTING INFO ON SUBJECT'S FILE

WRITE (NT,33) NS,SN,I,RES,NRW,PH(I),PL(I),R,T,AV(J),RR,PR,LL,IN1,NE,IT(1),IT(2),IT3

IF (J.GE.4) GO TO 65
IF (LL.NE.0) J=J+1
LL=0

IF (I.LE.40) GO TO 16
IF (LG.EQ.  1) GO TO 888
LG=1
C ### ADMINISTER SECOND TEST
GO TO (601,602),NQ
NQ=2
WRITE (6,501)
501 FORMAT (' HERE ARE SOME NUMERICAL ANALOGIES. . ,/,
1' THE PROCEDURE FOR ANSWERING THEM IS THE SAME. . ,/
GO TO 646
NQ=1
WRITE (6,502)
502 FORMAT (' HERE ARE SOME VERBAL ANALOGIES. ,/,
1' THE PROCEDURE FOR ANSWERING THEM IS THE SAME. ,/
DO 656 IL=1,35
READ (NQ,661) AL
GO TO 102
WRITE (6,1002)
1002 FORMAT (' YOUR STUDENT NUMBER IS NOT IN THE ID TABLE - CALL RON')
STOP 1001
STOP 804
STOP 808
STOP 820
STOP 876
STOP 877
STOP 888
CALL TIME(6,0,IT)
GO TO 887
WRITE (6,3399)
3399 FORMAT (' ERROR ACCUMULATION PREVENTS FURTHER PROCESSING')
WRITE (6,1112)
1112 FORMAT (' THIS CONCLUDES THE COMPUTER PHASE OF THIS RESEARCH PROJECT,'/
2' INFORMATION CONCERNING THE DESIGN AND FINDINGS OF THE STUDY' /
3' WILL BE PROVIDED TO YOU IN CLASS AT A LATER DATE. ' ,/
4' THE TERMINAL WILL SHUT ITSELF OFF. ' ,/
5' PLEASE DO NOT TRY TO SIGN ON AGAIN. ' ,/
6' THANK YOU FOR YOUR PARTICIPATION. SEE YOU IN CLASS!!')
C ### MAINTAIN SCREEN DISPLAY FOR 15 SEC.
CALL RTWAIT(4500)
STOP
C ### DETERMINE AND RECORD FINAL TIMES
CALL TIME(6,0,IT)
I3=3
WRITE (NT,3336) I3,SN,IT,I,J,LL,LG,NQ,T,RR
3336 FORMAT(IX,I1,A8,3X,2A4,1X,3A4,5I5,2F12.6)
STOP 333
5321 CALL CLOSFL('8
STOP 000
END
APPENDIX C

Printed Instructions for 'sign-on' to CCTT
ORGANIZATIONAL BEHAVIOUR - RESEARCH PROJECT

PLACE: ROOM 207, CIVIL ENGINEERING BUILDING

DATES: WED. NOVEMBER 7 TO THURS. NOVEMBER 15/73

TIMES: ANY TIME OF DAY OR NIGHT AT YOUR CONVENIENCE
(SATURDAY AND HOLIDAY HOURS ARE 8 AM TO 5 PM)

TIME REQUIRED WILL BE APPROXIMATELY ONE HOUR

MATERIALS: THIS INSTRUCTION SHEET, YOUR SECTION NUMBER ______
YOUR STUDENT NUMBER ____________

INSTRUCTIONS:

1 GO TO ROOM 207 IN THE CIVIL ENGINEERING BUILDING. YOU WILL
SEE SEPARATE CARRELS, EACH WITH ITS OWN CATHODE RAY TERMINAL.
POSITION YOURSELF AT A VACANT TERMINAL WHICH IS DISPLAYING
'MTS' IN LARGE GREEN LETTERS.

2 FAMILIARIZE YOURSELF WITH THE KEYBOARD, PARTICULARLY NOTING
THE UPPER ROW WHICH CONTAINS THE NUMBERS 0 THROUGH 9, AND
THE BOTTOM ROW WHICH CONTAINS THE SPACE BAR (LONG & DARK)
AND THE 'ENTER' KEY TO ITS IMMEDIATE RIGHT.

3 NOW TYPE THE FOLLOWING LETTER KEYS:
   SIG RONL
   AND PRESS THE 'ENTER' KEY.
   NOW LOOK AT THE SCREEN. IT SHOULD SAY 'ENTER USER PASSWORD'.
   IF IT DOES NOT, REPEAT INSTRUCTION 3.

4 NOW TYPE THE FOLLOWING LETTER KEY:
   X
   AND PRESS THE 'ENTER' KEY.
   THE SCREEN SHOULD NOW SAY 'PLEASE ENTER YOUR SECTION NUMBER'.
   IF IT DOES NOT, REPEAT INSTRUCTION 4. IF A MESSAGE IS RETURNED
   INDICATING YOU CANNOT SIGN ON RIGHT NOW, TRY AGAIN LATER.

5 NOW TYPE YOUR SECTION NUMBER (A SINGLE DIGIT) AND PRESS 'ENTER'.
   THE TERMINAL SCREEN WILL PRODUCE FURTHER INSTRUCTIONS.

6 IF YOU ARE UNABLE TO GET FULLY SIGNED ON TO A TERMINAL OR HAVE
   TO ABANDON IT, PLEASE TYPE 'SIGNOFF' AND PRESS 'ENTER'.

7 IF PROBLEMS PERSIST THAT PREVENT YOU FROM COMPLETING THIS PHASE
   OF THE PROJECT, PLEASE CALL RON LONGBOTTOM AT 683-8711, L.3448,
   BETWEEN THE HOURS OF 8 AND 4:30 (WEEKDAYS).

* PLEASE OBSERVE THE FOLLOWING RULES : THEY ARE ESSENTIAL!!
   DO NOT PRESS ANY TERMINAL KEYS OTHER THAN THOSE MENTIONED.
   DO THE PROJECT ON YOUR OWN (WITHOUT YOUR FRIENDS).
   DO THE TERMINAL SESSION ONCE ONLY.

*** THANKS ***
APPENDIX D

Computer Verbal and Numerical Analogy Tests
INSTRUCTIONS

FOLLOWING ARE SOME ANALOGY QUESTIONS WE WOULD LIKE YOU TO ANSWER.

HERE IS AN EXAMPLE OF A WORD ANALOGY:

FEATHER : _________ : SCALE : FISH

(1) SWIM (2) AIR (3) WATER (4) BIRD (5) FLY

THIS IS THE WAY IT SHOULD READ:

"FEATHER IS TO BLANK AS SCALE IS TO FISH?"

YOU ARE TO CHOOSE THE WORD WHICH BEST COMPLETES THE ANALOGY.

IN THIS EXAMPLE, YOU MIGHT REASON THAT A SCALE GROWS ON A FISH

WHAT DOES A FEATHER GROW ON? LOOK AT THE FIVE POSSIBLE ANSWERS.

"BIRD" IS THE BEST ANSWER, SO YOU WOULD PRESS THE KEY WITH THE

NUMBER "4" ON IT AND THEN PRESS THE "ENTER" KEY. GO AHEAD AND TRY IT.

YOU WILL FIND THAT THE REASONING REQUIRED FOR EACH ANALOGY QUESTION

IS DIFFERENT, AND THAT THE BLANK MAY APPEAR IN ANY POSITION.

FOR EACH QUESTION YOU MUST DETERMINE THE MOST APPROPRIATE REASONING

AND THEN SELECT THE WORD WHICH BEST COMPLETES THE ANALOGY.

FOR EACH ANALOGY QUESTION, PRESS THE KEY WITH THE NUMBER OF THE

CORRECT ANSWER AND THEN PRESS THE "ENTER" KEY.

IF YOU ARE NOT SURE WHICH IS THE CORRECT ANSWER, PRESS THE

KEY WITH THE NUMBER "0" (TOP ROW) AND THEN PRESS THE "ENTER" KEY.

DO NOT PRESS ANY KEYS OTHER THAN THE NUMBER KEYS AND THE ENTER KEY.

PLEASE BE ASSURED THAT YOUR RESPONSES WILL BE KEPT IN STRICTEST CONFIDENCE.

PLEASE WORK QUICKLY. YOUR START AND FINISH TIMES WILL BE RECORDED.

PRESS 'ENTER' WHEN YOU ARE READY TO PROCEED.

443545343532144251431511514512412444423
938 646 875 625 438 354 896 771 604 604 563 167 958 896 521 750 542 396 896
563 729 646 479 833 750 813 667 521 188 875 792 729 667 354 563 875 833 604
973 622 676 243 216 189 784 351 459 622 297 243 595 568 297 568 405 297 676
541 351 324 216 405 243 486 378 243 081 703 568 405 459 189 216 784 703 541

011_________ : HUNTER :: DOCTOR : LAWYER
012(1) ENGINEER (2) GENTLEMAN (3) DRUNK (4) FISHERMAN (5) CITIZEN
021DIVE : SWIM :: DOVE : __________
022(1) TREE (2) COO (3) FLY (4) SWAM (5) SWIMMING
031_________ : CLOWN :: TALL : DWARF
032(1) SHORT (2) LAUGH (3) DULL (4) BEARD (5) CIRCUS
041_________ : BACON :: BREAST : HAM
042(1) STEAK (2) PIG (3) BABY (4) EGGS (5) WING
051_________ : MISS :: HUSBAND : MR
052(1) HOUSEWIFE (2) LADY (3) NURSE (4) LASS (5) QUEEN
061DULL : __________ : SHINY : SHARP
062(1) DUMB (2) KEEN (3) BRIGHT (4) BORING (5) DULL
071CHECK : __________ : CASH : MONEY
072(1) MARK (2) GOLD (3) NOTE (4) GIANT (5) GOOSE
081TREE : MAN :: SAP : __________
082(1) AXE (2) WOMAN (3) MAPLE (4) BLOOD (5) ARM
091PICK : VIOLIN :: __________ : BANJO
092(1) PLAY (2) SING (3) BOW (4) STRING (5) FIDDLE
101_________ : BEHIND :: DRAG : AHEAD
102(1) BEFORE (2) BESIDE (3) AFTER (4) PULL (5) PUSH
111GASOLINE : CAR :: __________ : CLOCK
INSTRUCTIONS

Following are some analogy questions we would like you to answer.

Here is an example of a number analogy:

746 : 4 :: 839 : _________

(1) 9  (2) 4  (3) 76  (4) 8  (5) 3

This is the way it should read:
"First number is to second number as third number is to blank?"
You are to choose the number which best completes the analogy.
In this example, you might reason that the number "4" is in the middle of number 746. What number is in the middle of 839?
Look at the five possible answers. Since the number "3" is in the middle of 839, you would press the key with the number "5" on it and then press the "Enter" key. Go ahead and try it.

You will find that the reasoning required for each analogy question is different, and that the blank may appear in any position.
For each question you must determine the most appropriate reasoning and then select the word which best completes the analogy.

For each analogy question, press the key with the number of the correct answer and then press the "Enter" key.
If you are not sure which is the correct answer, press the key with the number "0" (top row) and then press the "Enter" key.

Do not press any keys other than the number keys and the enter key.
Please be assured that your responses will be kept in strictest confidence.
Please work quickly. Your start and finish times will be recorded.

Press 'Enter' when you are ready to proceed.
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<td>112</td>
<td>(1) 7 (2) 4 (3) 3 (4) 2 (5) 5 78</td>
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APPENDIX E

Valid Student Numbers and Section

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APPENDIX F

Subject's Test Record

Partial Computer File
Codes for Subject's Test Record

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<td>Question Identification</td>
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<tr>
<td>C</td>
<td>Item Response</td>
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<td>D</td>
<td>Correct/Incorrect Indicator (100 = Correct, 1 = Incorrect)</td>
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<td>E</td>
<td>High Group Probability Level</td>
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<td>F</td>
<td>Low Group Probability Level</td>
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<td>I</td>
<td>A Level In Effect</td>
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<td>Total Number of Items Right</td>
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<tr>
<td>K</td>
<td>Total Percent of Items Right</td>
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<tr>
<td>L</td>
<td>Subject Classification Indicator (9 = High, 1 = Low, 0 = None)</td>
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<td>M</td>
<td>Number of Program Interrupts</td>
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<td>N</td>
<td>Number of Terminal Operation Errors</td>
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<td>O</td>
<td>Total CPU (Central Processing Unit) Time</td>
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<td>Total Elapsed Time</td>
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<td>Q</td>
<td>Elapsed Item Response Time</td>
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APPENDIX G

Relative Cost Comparison of
CCTT and Paper Testing
APPENDIX G

RELATIVE COST COMPARISON OF CCTT AND PAPER TESTING

The following cost comparison is based on certain arbitrary assumptions regarding conventional test administration and should thus be treated with caution. Computing costs quoted are particular to the installation and approximate actual costs. Capital investment, overhead and material costs are ignored. An average group setting of 10 subjects is assumed.

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<tr>
<td></td>
<td>Numerical</td>
<td>32 min.</td>
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<td></td>
<td>Instructions, etc.</td>
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<tr>
<td></td>
<td>Scoring and recording (10 tests at 2.5 min.)</td>
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<td>81 min.</td>
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Test administration and scoring costs per hour $5.00 (assumed)

Cost per subject = \$5.00 \times \frac{81}{60} = \$0.675

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CPU and Terminal Connect Costs

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<td>Numerical</td>
<td>1.200 sec.</td>
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<td></td>
<td>2.301 sec.</td>
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Terminal connect cost $3/hr. = $3 \times \frac{11.39}{60} = $0.569

CPU cost at $250/hr. = $250 \times \frac{1.101}{60} = $4.161

Cost per subject = $0.569 + $4.161 = $4.730