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# A Comparison of the Effects of Random Versus Fixed Order of Item Presentation Via the Computer

## Research Report ONR89-1

Terry A. Ackerman
Judith A. Spray
Mark D. Reckase
James E. Carlson

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## ABSTRACT

The effect of random versus fixed order of item presentation was studied using a computerized testing system at the Marine Corps Communication-Electronics School (MCCES) at the Twentynine Palms Marine Base in southern California. Classes from four different annexes were randomly divided between the two administrative formats. Similar results were found for each annex. The results suggest that when MCCES items are administered via the computer, order of item presentation makes at most a very small difference. Implications and future directions are discussed.

# A COMPARISON OF THE EFFECTS OF RANDOM VERSUS FIXED ORDER OF ITEM PRESENTATION VIA THE COMPUTER

## Introduction

As part of the research on the Office of Naval Research Contract N00014-85-C0241, a computerized testing system was designed and installed at the Marine Corps Communication-Electronics School (MCCES) at the Twentynine Palms Marine Base in southern California. The hardware was designed as part of a research project which had three phases. Phase I was designed to compare paper and pencil and computer-administered modes of test administration. In the second phase, all testing utilized the computer administration mode and comparisons of the effects of random vs. fixed item order were investigated. The final phase consisted of implementating a complete computerized adaptive testing system using item parameter estimates which were calibrated from Phase I and Phase II response data.

Results from Phase I are completely described in (Spray, Ackerman, Carlson & Reckase, 1985.) This report, which summarizes the results of Phase II, parallels the Phase I report.

## Method

In Phase II, the effect of random versus fixed item order was studied in four courses called "annexes": GR01, GR02, GR03 and GR05. For the purposes of this study, classes within each of the four annexes were divided into two groups according to the last four digits of their social security number. If a student's social security number was odd he or she would be assigned to a "fixed order" group; if the number was even he or she was assigned to a "random order" group. Both groups were given the exact same items, however, each member of the fixed group was presented the items in exactly the same

fixed order; where as each member of the random group was presented the items in a different random arrangement. All tests for each of the four annexes were 25 items in length.

During the period of this study 13 classes were tested in GR01, 12 classes in GR02, 14 classes in GR03, and 15 classes in GR05. The number of students who were administered items in a fixed order were 131, 143, 127 and 87 for annexes GR01, GR02, GR03 and GR05, respectively. The number who received items in a random order were 138, 123, 137 and 108, respectively.

The item pool for GR01 was the largest, containing 83 items. Item pools for each of the remaining annexes contained 75 items each. Items were pseudo-randomly selected without replacement to comprise the 25-item tests. Thus each of the 25-item tests consisted of different items, and no items were allowed to repeat until every third class.

A typical testing session was as follows:

1.  A student was randomly assigned to either a fixed or random item presentation format by the computer after logging on.

2.  Students would respond to items using a series of training manuals containing schematics and other pertinent wiring diagrams. Sometimes students would have to refer to several manuals to arrive at the answer.

3.  Students could also use scrap paper for simple calculations as well as any class notes that they may have written into their manuals.

4.  Each testing session would last 125 minutes and was monitored by at least one instructor.

5.  If students completed the test early, they could sign off their computer and leave the room.

6.  A review of the test and results was conducted immediately following the testing session.

## Results

Data collection from the equivalent groups started in November of 1987 and concluded in June of 1988. Based on the analysis of these data, it was concluded that although some statistically significant differences existed, no substantial, practical real differences between the two administrative formats were detected.

Total test score comparisons were made between testing formats for each of the four annexes. Figures 1, 2, 3 and 4 display the 95% confidence intervals about the total test score for both the pencil and paper and the computer groups for each class for each annex. In all cases except two, the confidence bands overlap indicating a nonsignificant difference between the mean test scores for each format. Only for the third and thirteenth GRO3 classes do the confidence bands not overlap. These can be partly explained by the small sample, $N = 3$, for both the computer groups for each of these classes.

Mean scores and standard deviations for each class for each annex are shown in Tables 1, 2, 3 and 4. A two-way analysis of variance was performed on each class to determine whether any class or administration median effect was present.

Between-class differences yielded ANOVA F-statistics and p-values of $F(12,110) = 1.82$, $p = .0540$; $F(11,162) = 21.95$, $p < .0000$, $F(13,112) = 3.58$, $p < .0001$; and, $F(11,91) = 1.67$, $p = .0925$ for each of the four respective annexes. Between-format differences were $F(1,114) = .10$, $p = .7547$; $F(1,163) = 1.03$, $p = .3117$; $F(1,121) = 1.97$, $p = .1626$; and, $F(1,94) = 3.98$, $p = .0490$ respectively. All tests of the interaction between class and administrative formats were nonsignificant.

Annex GR05 was the only annex to yield a difference in mean scores that was significant at the .05 level. This was also the annex on which the students scored the highest, possibly resulting in some restriction of range effects, resulting in smaller standard deviations for the scores.

Tests between the empirical cummulative raw score distributions were also computed. The cummulative distributions are graphically displayed in Figures 5, 6, 7, and 8, respectively.

A two-sided Kolmogorov-Smirnov test of no cummulative distribution differences was computed for each annex. The test statistics, T, and the associated p-value for GR01, GR02, GR03 and GR05 were $T = .519$, $p = .950$; $T = .774$, $p = .586$; $T = .631$, $p = .821$, and $T = 1.028$, $p = .241$, respectively. The fact that the Kolnogerov-Smirnov has slightly less power than the ANOVA, may explain the differences in the results. However, the two analyses show that any differences are difficult to interpret.

Frequency distributions of the proportion-correct values were similar for both administrative formats across the four annexes. These results are displayed in Table 5. Note also that the proportion-correct also shown for items to which at least 50 examinees responded.

Stepwise logistic regression analyses were performed on each item within each annex to test for administrative format differences of item discrimination and item difficulty. The process is described in detail in the Appendix. The results of the item logistic regression analyses are reported by annex in Tables 6, 7, 8 and 9. In all, 308 items were tested. Of the items tested, seven items had difficulty (format) differences at a probability less than .01. These items were numbers 60 and 68 from GR01; 13, 23, 41 and 50 from GR03; and 43 from GR05. Discrimination (format X score) differences for five items were determined to be significant at the same level: numbers 30 and 44

from GRO1; 8 and 30 from GRO2; and 60 from GRO3. The position of each of these items in both the fixed and random order formats were examined. No consistent pattern of a shift in difficulty or discrimination was found to coincide with a shift in item location.

For the majority of items the power to detect difficulty or discrimination differences may have been extremely small because of the small sample sizes. Also because of the criterion-referenced nature of the test, most of the items tended to have a high proportion-correct values, thus making item difficulty or discrimination parameters more homogeneous.

## Summary

The results of this eight month research study suggest that when the GRRC items are administered via the computer, order of item presentation makes at most a very small difference. This would imply a lack of dependence between items. That is, the response to a given item is not affected by responses to any previous items, nor will it effect the response to any subsequent items.

Items which were found to have either statistically significant difficulty or discrimination differences were reviewed for possible clues as to why the differences exist. An analysis of the surface features of the items revealed no clue to the cause of the differences, if indeed the differences are real. Given that three significant values would be expected by chance, the fact that there were only seven and five significant results found implies that any effects are very weak indeed. However, a detailed analysis of the items by content experts, or a thorough questioning of the students, might reveal some explanation for the minor differences that were detected. Such analyses were not completed.

# REFERENCES

Spray, J. A., Ackerman, T. A., Carlson, J. E., Reckase, M. D. (1985). Comparison of the effects of presentation mode on characteristics of test scores and test items. (ONR Research Report). Iowa City, IA: American College Testing Program.

## TABLE 1

### Test Score Summary Statistics by Class—GR01

| | Fixed Order | | | | Random Order | | |
|---|---|---|---|---|---|---|---|
| Class | N | $\bar{X}$ | SD | | N | $\bar{X}$ | SD |
| 1 | 8 | 19.8 | 3.2 | | 9 | 19.2 | 1.9 |
| 2 | 5 | 19.0 | 3.4 | | 11 | 20.3 | 2.1 |
| 3 | 11 | 20.8 | 2.5 | | 11 | 20.3 | 3.0 |
| 4 | 11 | 19.4 | 3.2 | | 14 | 20.1 | 1.7 |
| 5 | 9 | 21.6 | 1.9 | | 14 | 21.5 | 1.7 |
| 6 | 11 | 20.5 | 2.5 | | 11 | 20.0 | 2.6 |
| 7 | 11 | 19.6 | 1.7 | | 13 | 20.8 | 2.0 |
| 8 | 11 | 20.8 | 2.0 | | 11 | 20.5 | 2.2 |
| 9 | 6 | 21.8 | 1.5 | | 12 | 20.2 | 3.1 |
| 10 | 13 | 20.0 | 2.1 | | 7 | 19.4 | .8 |
| 11 | 13 | 19.6 | 2.8 | | 10 | 21.0 | 2.1 |
| 12 | 13 | 21.3 | 1.8 | | 6 | 22.0 | 1.9 |
| 13 | 9 | 20.4 | 2.5 | | 9 | 18.2 | 3.8 |
| Overall | 131 | 20.4 | 2.4 | | 138 | 20.5 | 2.9 |

## TABLE 2

### Test Score Summary Statistics by Class—GRO2

| | Fixed Order | | | | Random Order | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Class | N | $\bar{X}$ | SD | | N | $\bar{X}$ | SD |
| 1 | 12 | 16.7 | 2.1 | | 8 | 14.1 | 2.9 |
| 2 | 9 | 21.7 | 2.2 | | 13 | 19.8 | 2.6 |
| 3 | 10 | 21.5 | 1.6 | | 11 | 21.7 | 2.0 |
| 4 | 9 | 21.1 | 3.1 | | 14 | 21.9 | 2.3 |
| 5 | 12 | 20.7 | 3.9 | | 10 | 20.5 | 2.5 |
| 6 | 8 | 14.9 | 2.0 | | 15 | 15.6 | 2.2 |
| 7 | 13 | 17.2 | 1.7 | | 8 | 16.8 | 2.6 |
| 8 | 15 | 16.1 | 1.6 | | 10 | 16.7 | 1.9 |
| 9 | 12 | 16.7 | 2.1 | | 8 | 14.1 | 2.9 |
| 10 | 13 | 17.2 | 1.7 | | 8 | 16.8 | 2.6 |
| 11 | 12 | 19.2 | 3.4 | | 6 | 21.0 | 1.7 |
| 12 | 18 | 18.1 | 2.7 | | 12 | 18.0 | 2.6 |
| Overall | 143 | 18.3 | 3.1 | | 123 | 18.3 | 3.5 |

## TABLE 3

### Test Score Summary Statistics by Class--GR03

| | Fixed Order | | | | Random Order | | |
|---|---|---|---|---|---|---|---|
| Class | N | $\bar{X}$ | SD | | N | $\bar{X}$ | SD |
| 1 | 5 | 20.2 | 3.7 | | 7 | 20.3 | 2.1 |
| 2 | 8 | 16.3 | 2.2 | | 8 | 16.5 | 3.5 |
| 3 | 12 | 20.0 | 1.9 | | 3 | 17.7 | .6 |
| 4 | 8 | 19.0 | 3.2 | | 11 | 18.3 | 2.8 |
| 5 | 10 | 19.7 | 2.9 | | 13 | 18.1 | 2.5 |
| 6 | 9 | 19.3 | 3.1 | | 15 | 18.5 | 3.7 |
| 7 | 8 | 17.9 | 2.6 | | 15 | 17.5 | 3.1 |
| 8 | 14 | 17.1 | 4.0 | | 11 | 17.7 | 4.3 |
| 9 | 6 | 18.3 | 2.8 | | 13 | 17.2 | 2.0 |
| 10 | 10 | 21.1 | 2.2 | | 9 | 19.2 | 3.7 |
| 11 | 5 | 20.2 | 3.7 | | 7 | 20.3 | 2.1 |
| 12 | 8 | 16.3 | 2.2 | | 8 | 16.5 | 3.5 |
| 13 | 12 | 19.7 | 1.9 | | 3 | 17.7 | .6 |
| 14 | 12 | 18.4 | 2.5 | | 12 | 20.3 | 2.4 |
| Overall | 127 | 18.8 | 3.0 | | 137 | 18.3 | 3.1 |

## TABLE 4

### Test Score Summary Statistics by Class – GR05

| | Fixed Order | | | | Random Order | | |
| Class | N | $\bar{X}$ | SD | | N | $\bar{X}$ | SD |
|---|---|---|---|---|---|---|---|
| 1 | 7 | 20.4 | 2.2 | | 6 | 20.7 | 3.1 |
| 2 | 6 | 21.5 | 1.9 | | 7 | 20.7 | .8 |
| 3 | 6 | 20.8 | 3.2 | | 5 | 20.8 | 2.4 |
| 4 | 8 | 22.6 | 1.8 | | 14 | 22.1 | 2.2 |
| 5 | 5 | 21.8 | 1.6 | | 12 | 19.8 | 3.2 |
| 6 | 7 | 20.3 | 3.4 | | 5 | 19.6 | 1.1 |
| 7 | 6 | 21.0 | 1.3 | | 14 | 18.7 | 2.4 |
| 8 | 4 | 21.8 | 2.6 | | 13 | 19.9 | 3.7 |
| 9 | 10 | 21.3 | 2.5 | | 7 | 21.9 | 2.0 |
| 10 | 6 | 21.5 | 1.6 | | 8 | 22.3 | 1.8 |
| 11 | 10 | 22.4 | 2.5 | | 6 | 20.7 | 2.3 |
| 12 | 12 | 20.3 | 2.1 | | 11 | 20.3 | 2.4 |
| Overall | 87 | 21.3 | 2.3 | | 108 | 20.5 | 2.7 |

**Table 5**

**Frequency Distributions of Proportion Correct Values**

| $p$ | GR01 | | GR02 | | GR03 | | GR05 | |
|---|---|---|---|---|---|---|---|---|
| | Fixed | Random | Fixed | Random | Fixed | Random | Fixed | Random |
| .90-1.00 | 39 (12) | 41 (11) | 20 (12) | 27 (12) | 22 (5) | 15 (6) | 41 (0) | 32 (2) |
| .80-.89 | 16 (5) | 14 (4) | 19 (9) | 13 (7) | 13 (5) | 14 (4) | 7 (0) | 22 (3) |
| .70-.79 | 10 (3) | 8 (0) | 16 (7) | 7 (3) | 11 (3) | 18 (9) | 7 (0) | 9 (3) |
| .60-.69 | 6 (1) | 8 (1) | 3 (2) | 14 (4) | 13 (2) | 9 (2) | 4 (0) | 3 (1) |
| .50-.59 | 8 (4) | 7 (0) | 3 (0) | 2 (1) | 6 (0) | 12 (6) | 4 (0) | 5 (2) |
| .40-.49 | 1 (0) | 2 (0) | 0 (0) | 0 (0) | 5 (1) | 3 (2) | 1 (0) | 3 (1) |
| .30-.39 | 3 (1) | 3 (0) | 3 (0) | 1 (0) | 4 (2) | 2 (1) | 1 (0) | 1 (0) |
| .20-.29 | 0 (0) | 0 (0) | 1 (0) | 2 (1) | 1 (0) | 2 (1) | 0 (0) | 0 (0) |
| .10-.19 | 0 (0) | 0 (0) | 1 (0) | 1 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| .00-.09 | 0 (0) | 0 (0) | 9 (2) | 8 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Total Items | 83 (26) | 83 (16) | 75 (32) | 75 (28) | 75 (17) | 75 (31) | 75 (0) | 75 (12) |

Note: Frequencies in parentheses represent examinee samples $\geq$ 50.

## TABLE 6

### Logistic Regression Results of GRO1

| | | | Proportion Correct | | | Improvement $x^2$ p-values | |
| | | | | | | Format Effect | Format by Score Effect |
| Item # | $N_f$ | $N_r$ | f | r | | (Difficulty) | (Discrimination) |
|---|---|---|---|---|---|---|---|
| 1 | 11 | 11 | 1.00 | 1.00 | | 1.000 | 1.000 |
| 2 | 35 | 33 | .83 | .94 | | .285 | .955 |
| 4 | 21 | 19 | .52 | .68 | | .297 | .265 |
| 5 | 15 | 21 | 1.00 | 1.00 | | 1.000 | 1.000 |
| 6 | 11 | 11 | .91 | 1.00 | | .251 | .995 |
| 7 | 13 | 7 | .92 | .86 | | .549 | .466 |
| 8 | 11 | 11 | .91 | .91 | | .924 | .055 |
| 9 | 14 | 25 | 1.00 | 1.00 | | 1.000 | 1.000 |
| 10 | 39 | 45 | .97 | .96 | | .622 | .727 |
| 11 | 51 | 48 | .96 | .96 | | .961 | .207 |
| 12 | 53 | 64 | 1.00 | .98 | | .315 | .989 |
| 13 | 46 | 41 | .89 | .85 | | .578 | .748 |
| 14 | 43 | 43 | .88 | .84 | | .540 | .292 |
| 15 | 46 | 43 | .72 | .63 | | .318 | .637 |
| 16 | 53 | 64 | 1.00 | .94 | | .052 | .974 |
| 17 | 35 | 35 | 1.00 | 1.00 | | 1.000 | 1.000 |
| 18 | 38 | 42 | .74 | .71 | | .821 | .970 |
| 19 | 31 | 33 | .97 | 1.00 | | .223 | .987 |
| 20 | 50 | 53 | .84 | .85 | | .845 | .423 |
| 21 | 35 | 29 | .69 | .55 | | .303 | .419 |
| 22 | 44 | 61 | .80 | .80 | | .975 | .183 |
| 23 | 46 | 53 | .83 | .81 | | .815 | .205 |
| 24 | 56 | 47 | .80 | .81 | | .931 | .964 |
| 25 | 43 | 41 | .91 | 1.00 | | .018 | .984 |

Table 6, cont.

| Item # | $N_f$ | $N_r$ | $f$ | $r$ | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
|--------|-------|-------|------|------|------|------|
| | | | Proportion Correct | | Improvement $x^2$ p-values | |
| 26 | 27 | 32 | .89 | .91 | .814 | .601 |
| 27 | 53 | 58 | .92 | .90 | .566 | .678 |
| 28 | 30 | 31 | .97 | 1.00 | .213 | .988 |
| 29 | 61 | 67 | .74 | .70 | .679 | .230 |
| 30 | 48 | 47 | .81 | .89 | .066 | .000 |
| 31 | 23 | 34 | .96 | .85 | .208 | .046 |
| 32 | 54 | 50 | .98 | .98 | .988 | .435 |
| 33 | 54 | 54 | .96 | .96 | .996 | .235 |
| 34 | 29 | 29 | 1.00 | .90 | .037 | .995 |
| 35 | 50 | 56 | .98 | .96 | .612 | .472 |
| 36 | 52 | 53 | 1.00 | 1.00 | 1.000 | 1.000 |
| 37 | 54 | 55 | .98 | .98 | .968 | .445 |
| 38 | 39 | 43 | .97 | .95 | .628 | .723 |
| 39 | 39 | 40 | .80 | .75 | .978 | .499 |
| 40 | 63 | 67 | .95 | .97 | .593 | .554 |
| 41 | 44 | 43 | .98 | .98 | .963 | .469 |
| 42 | 25 | 33 | .92 | .97 | .349 | .923 |
| 43 | 41 | 41 | .51 | .49 | .803 | .557 |
| 44 | 48 | 47 | .38 | .34 | .740 | .004 |
| 45 | 41 | 45 | 1.00 | 1.00 | 1.000 | 1.000 |
| 46 | 26 | 40 | 1.00 | 1.00 | 1.000 | 1.000 |
| 47 | 56 | 44 | .98 | 1.00 | .307 | .989 |
| 48 | 49 | 54 | .90 | .93 | .622 | .789 |
| 49 | 33 | 30 | .97 | .93 | .949 | .073 |
| 50 | 35 | 32 | .94 | 1.00 | .106 | .999 |

Table 6, cont.

| Item # | $N_f$ | $N_r$ | Proportion Correct | | | Improvement $\times^2$ p-values | |
|:---:|:---:|:---:|:---:|:---:|:---:|:---:|:---:|
| | | | | | | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
| | | | $f$ | $r$ | | | |
| 51 | 13 | 6 | 1.00 | 1.00 | | 1.000 | 1.000 |
| 52 | 15 | 26 | 1.00 | .96 | | .338 | .999 |
| 53 | 16 | 22 | .88 | .91 | | .740 | .409 |
| 54 | 19 | 22 | .68 | .82 | | .335 | .178 |
| 55 | 33 | 31 | 1.00 | 1.00 | | 1.000 | 1.000 |
| 56 | 51 | 56 | .55 | .75 | | .029 | .379 |
| 57 | 53 | 46 | .32 | .26 | | .536 | .976 |
| 58 | 28 | 32 | .64 | .78 | | .128 | 1.000 |
| 59 | 53 | 64 | .57 | .50 | | .563 | .549 |
| 60 | 74 | 72 | .93 | 1.00 | | .005 | .985 |
| 61 | 49 | 48 | .94 | .88 | | .294 | .545 |
| 62 | 24 | 21 | .50 | .71 | | .155 | .906 |
| 63 | 50 | 53 | .62 | .57 | | .859 | .078 |
| 64 | 42 | 37 | .69 | .49 | | .028 | .384 |
| 65 | 44 | 59 | .50 | .48 | | .859 | .463 |
| 66 | 27 | 35 | .74 | .91 | | .076 | .905 |
| 67 | 53 | 49 | .81 | .88 | | .414 | .777 |
| 68 | 20 | 25 | .70 | .28 | | .004 | .951 |
| 69 | 25 | 34 | .36 | .59 | | .068 | .420 |
| 70 | 59 | 52 | .75 | .69 | | .453 | .612 |
| 71 | 53 | 55 | .59 | .64 | | .503 | .460 |
| 72 | 52 | 55 | .56 | .53 | | .691 | .603 |
| 73 | 38 | 40 | .82 | .73 | | .341 | .480 |
| 74 | 38 | 44 | .74 | .61 | | .189 | .103 |
| 75 | 61 | 64 | .80 | .83 | | .692 | .906 |

**Table 6, cont.**

| Item # | $N_f$ | $N_r$ | Proportion Correct | | Improvement $x^2$ p-values | |
|---|---|---|---|---|---|---|
| | | | | | Format Effect | Format by Score Effect |
| | | | $f$ | $r$ | (Difficulty) | (Discrimination) |
| 76 | 65 | 61 | .89 | .89 | .900 | .765 |
| 77 | 39 | 45 | .72 | .69 | .755 | .479 |
| 78 | 28 | 37 | .89 | .95 | .398 | .058 |
| 79 | 33 | 32 | .64 | .66 | .864 | .835 |
| 80 | 30 | 29 | .73 | .76 | .768 | .407 |
| 81 | 37 | 39 | .97 | .90 | .143 | .378 |
| 82 | 69 | 75 | .75 | .64 | .155 | .111 |
| 83 | 46 | 46 | .43 | .54 | .316 | .472 |
| 84 | 25 | 33 | .92 | .94 | .756 | .131 |

## TABLE 7

### Logistic Regression Results of GRO2

| Item # | $N_f$ | $N_r$ | f | r | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
|---|---|---|---|---|---|---|
| | | | Proportion Correct | | Improvement $x^2$ p-values | |
| 1 | 30 | 18 | .87 | .94 | .390 | .013 |
| 2 | 34 | 31 | .00 | .03 | .252 | .994 |
| 3 | 39 | 26 | .82 | .65 | .685 | .063 |
| 4 | 47 | 41 | .00 | .00 | 1.000 | 1.000 |
| 5 | 30 | 18 | .77 | .78 | .991 | .348 |
| 6 | 26 | 16 | 1.00 | 1.00 | 1.000 | 1.000 |
| 7 | 58 | 47 | .03 | .06 | .484 | .795 |
| 8 | 15 | 10 | .33 | .20 | .434 | .004 |
| 9 | 30 | 18 | .90 | .90 | .802 | .163 |
| 10 | 63 | 53 | .97 | .98 | .643 | .635 |
| 11 | 42 | 43 | .74 | .65 | .349 | .799 |
| 12 | 22 | 17 | .77 | .82 | .910 | .549 |
| 13 | 70 | 60 | .94 | .95 | .775 | .516 |
| 14 | 78 | 75 | .73 | .71 | .748 | .651 |
| 15 | 80 | 81 | .68 | .57 | .176 | .138 |
| 16 | 26 | 16 | .31 | .38 | .590 | .049 |
| 17 | 44 | 37 | .00 | .08 | .051 | .992 |
| 18 | 33 | 22 | .67 | .77 | .397 | .950 |
| 19 | 74 | 79 | .60 | .61 | .866 | .950 |
| 20 | 55 | 46 | .87 | .80 | .369 | .110 |
| 21 | 73 | 70 | .90 | .94 | .470 | .439 |
| 22 | 44 | 48 | .89 | .81 | .306 | .055 |
| 23 | 71 | 56 | .89 | .96 | .082 | .090 |
| 24 | 40 | 29 | .88 | .97 | .202 | .748 |
| 25 | 63 | 73 | .92 | .90 | .726 | .726 |

Table 7 (cont.)

| | | | Proportion Correct | | Improvement $\times^2$ p-values | |
|---|---|---|---|---|---|---|
| Item # | $N_f$ | $N_r$ | $f$ | $r$ | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
| 26 | 74 | 65 | .88 | .82 | .232 | .860 |
| 27 | 46 | 33 | .89 | .73 | .096 | .623 |
| 28 | 72 | 53 | .90 | .89 | .148 | .742 |
| 29 | 38 | 48 | .55 | .92 | .568 | .010 |
| 30 | 33 | 22 | .76 | .86 | .339 | .001 |
| 31 | 30 | 18 | .93 | .94 | .936 | .312 |
| 32 | 44 | 48 | .89 | .81 | .325 | .297 |
| 33 | 69 | 57 | .71 | .67 | .628 | .210 |
| 34 | 57 | 52 | 1.00 | 1.00 | 1.000 | 1.000 |
| 35 | 70 | 66 | .93 | .94 | .864 | .867 |
| 36 | 56 | 53 | .98 | 1.00 | .299 | .974 |
| 37 | 34 | 27 | .94 | .96 | .543 | .089 |
| 38 | 68 | 59 | .99 | .92 | .061 | .044 |
| 39 | 41 | 45 | .93 | .93 | .988 | .153 |
| 40 | 15 | 10 | .93 | 1.00 | .096 | .931 |
| 41 | 30 | 18 | .80 | .94 | .159 | .192 |
| 42 | 64 | 53 | .78 | .70 | .315 | .403 |
| 43 | 69 | 67 | .88 | .84 | .428 | .977 |
| 44 | 74 | 79 | .95 | .90 | .271 | .095 |
| 45 | 12 | 6 | .08 | .60 | .891 | .947 |
| 46 | 44 | 28 | .07 | .07 | .972 | .012 |
| 47 | 33 | 22 | .21 | .18 | .792 | .515 |
| 48 | 61 | 60 | .98 | .97 | .469 | .463 |
| 49 | 55 | 47 | .71 | .66 | .549 | .043 |
| 50 | 70 | 66 | .81 | .82 | .751 | .458 |
| 51 | 62 | 64 | .76 | .64 | .170 | .433 |
| 52 | 50 | 32 | .08 | .00 | .015 | .983 |
| 53 | 59 | 51 | .19 | .22 | .272 | .926 |
| 54 | 33 | 22 | .00 | .00 | 1.000 | 1.000 |
| 55 | 34 | 31 | .79 | .68 | .518 | .974 |

Table 7, cont.

| Item # | $N_f$ | $N_r$ | Proportion Correct | | Improvement $x^2$ p-values | |
| | | | $f$ | $r$ | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
|---|---|---|---|---|---|---|
| 56 | 89 | 81 | .80 | .64 | .045 | .803 |
| 57 | 39 | 26 | .00 | .00 | 1.000 | 1.000 |
| 58 | 65 | 52 | .86 | .83 | .440 | .821 |
| 59 | 26 | 16 | .39 | .50 | .350 | .001 |
| 60 | 55 | 58 | .86 | .86 | .992 | .154 |
| 61 | 38 | 33 | .76 | .94 | .016 | .618 |
| 62 | 39 | 26 | .74 | .65 | .442 | .365 |
| 63 | 50 | 32 | .76 | .69 | .867 | .894 |
| 64 | 47 | 47 | .77 | .70 | .436 | .619 |
| 65 | 39 | 26 | .90 | .96 | .297 | .239 |
| 66 | 44 | 28 | .52 | .61 | .466 | .845 |
| 67 | 36 | 22 | 1.00 | .91 | .162 | .986 |
| 68 | 34 | 31 | .71 | .87 | .105 | .187 |
| 69 | 63 | 73 | .75 | .75 | .924 | .776 |
| 70 | 39 | 26 | .82 | .69 | .133 | .121 |
| 71 | 61 | 60 | .90 | .83 | .128 | .054 |
| 72 | 53 | 62 | .87 | .90 | .602 | .281 |
| 73 | 26 | 16 | .85 | 1.00 | .037 | .996 |
| 74 | 12 | 6 | .83 | 1.00 | .231 | .998 |
| 75 | 36 | 22 | .58 | .68 | .076 | .151 |

Table 8

Logistic Regression Results of GR03

| Item # | $N_f$ | $N_r$ | $f$ | $r$ | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
|---|---|---|---|---|---|---|
| | | | Proportion Correct | | Improvement $x^2$ p-values | |
| 1 | 41 | 51 | .98 | 1.00 | .204 | .987 |
| 2 | 48 | 43 | .98 | .98 | .829 | .089 |
| 3 | 38 | 41 | .84 | .85 | .900 | .500 |
| 4 | 34 | 19 | .32 | .37 | .255 | .056 |
| 5 | 44 | 52 | .96 | .96 | .980 | .731 |
| 6 | 49 | 64 | .65 | .77 | .152 | .327 |
| 7 | 48 | 43 | 1.00 | 1.00 | 1.000 | 1.000 |
| 8 | 45 | 52 | 1.00 | .96 | .096 | .990 |
| 9 | 34 | 40 | .53 | .50 | .967 | .864 |
| 10 | 40 | 53 | .63 | .59 | .792 | .728 |
| 11 | 40 | 50 | .75 | .84 | .276 | .969 |
| 12 | 47 | 32 | .92 | .75 | .064 | .695 |
| 13 | 68 | 53 | .88 | .64 | .001 | .361 |
| 14 | 28 | 38 | .71 | .63 | .564 | .429 |
| 15 | 31 | 44 | 1.00 | .89 | .019 | .994 |
| 16 | 41 | 51 | .68 | .59 | .337 | .361 |
| 17 | 44 | 28 | .98 | 1.00 | .204 | .986 |
| 18 | 42 | 56 | .43 | .39 | .785 | .461 |
| 19 | 44 | 49 | .64 | .78 | .063 | .107 |
| 20 | 45 | 52 | .76 | .85 | .383 | .022 |
| 21 | 43 | 56 | .35 | .43 | .451 | .204 |
| 22 | 31 | 41 | .55 | .59 | .988 | .198 |
| 23 | 40 | 40 | .58 | .85 | .003 | .943 |
| 24 | 52 | 39 | .94 | .85 | .479 | .763 |
| 25 | 48 | 51 | .77 | .65 | .175 | .618 |

Table 8, cont.

| | | | Proportion Correct | | | Improvement $\chi^2$ p-values | |
|---|---|---|---|---|---|---|---|
| Item # | $N_f$ | $N_r$ | $f$ | $r$ | | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
| 26 | 32 | 40 | .69 | .76 | | .432 | .123 |
| 27 | 50 | 41 | .96 | .93 | | .602 | .996 |
| 28 | 26 | 29 | .69 | .66 | | .772 | .411 |
| 29 | 50 | 62 | .76 | .77 | | .610 | .018 |
| 30 | 58 | 44 | .86 | .86 | | .876 | .755 |
| 31 | 40 | 51 | .88 | .75 | | .059 | .937 |
| 32 | 41 | 32 | .68 | .72 | | .514 | .346 |
| 33 | 52 | 44 | .31 | .52 | | .027 | .406 |
| 34 | 36 | 49 | .69 | .80 | | .151 | .964 |
| 35 | 36 | 54 | .42 | .52 | | .342 | .098 |
| 36 | 33 | 40 | .55 | .53 | | .757 | .552 |
| 37 | 53 | 44 | .91 | .91 | | .794 | .970 |
| 38 | 38 | 34 | 1.00 | .97 | | .469 | .982 |
| 39 | 41 | 53 | .73 | .55 | | .101 | .827 |
| 40 | 53 | 63 | .81 | .86 | | .613 | .664 |
| 41 | 36 | 38 | .94 | .63 | | .000 | .403 |
| 42 | 38 | 34 | .76 | .77 | | .721 | .064 |
| 43 | 35 | 51 | .86 | .71 | | .222 | .567 |
| 44 | 41 | 32 | .56 | .53 | | .835 | .239 |
| 45 | 51 | 46 | .94 | .85 | | .222 | .569 |
| 46 | 54 | 61 | .80 | .78 | | .686 | .035 |
| 47 | 58 | 65 | .79 | .71 | | .193 | .468 |
| 48 | 40 | 53 | .88 | .70 | | .055 | .405 |
| 49 | 36 | 38 | .86 | .63 | | .024 | .823 |
| 50 | 40 | 40 | .98 | .78 | | .004 | .018 |

Table 8, cont.

| Item # | $N_f$ | $N_r$ | Proportion Correct | | Improvement $x^2$ p-values | |
| | | | $f$ | $r$ | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
|---|---|---|---|---|---|---|
| 51 | 37 | 54 | .97 | .94 | .503 | .293 |
| 52 | 64 | 52 | .41 | .29 | .314 | .364 |
| 53 | 20 | 27 | .90 | .96 | .330 | .961 |
| 54 | 32 | 21 | .91 | .67 | .065 | .399 |
| 55 | 66 | 50 | .33 | .46 | .095 | .270 |
| 56 | 34 | 19 | .91 | 1.00 | .031 | .990 |
| 57 | 51 | 46 | .69 | .76 | .467 | .853 |
| 58 | 33 | 42 | .49 | .41 | .479 | .235 |
| 59 | 58 | 65 | .78 | .72 | .352 | .950 |
| 60 | 19 | 29 | .21 | .24 | .849 | .002 |
| 61 | 35 | 51 | .80 | .90 | .110 | .237 |
| 62 | 49 | 51 | .49 | .59 | .227 | .287 |
| 63 | 42 | 49 | .62 | .59 | .845 | .473 |
| 64 | 37 | 49 | .89 | .86 | .823 | .586 |
| 65 | 34 | 51 | .88 | .92 | .274 | .454 |
| 66 | 44 | 54 | .68 | .70 | .804 | .342 |
| 67 | 54 | 43 | .87 | .88 | .772 | .192 |
| 68 | 44 | 47 | .71 | .66 | .743 | .871 |
| 69 | 44 | 33 | .68 | .79 | .191 | .078 |
| 70 | 26 | 29 | .54 | .79 | .055 | .775 |
| 71 | 52 | 44 | .90 | .89 | .933 | .562 |
| 72 | 30 | 44 | .70 | .66 | .719 | .858 |
| 73 | 52 | 65 | .63 | .59 | .588 | .610 |
| 74 | 38 | 52 | .90 | .85 | .497 | .707 |
| 75 | 47 | 32 | .98 | .97 | .766 | .745 |

## TABLE 9

### Logistic Regression Results of GR05

| Item # | $N_f$ | $N_r$ | Proportion Correct | | Improvement $x^2$ p-values | |
| | | | f | r | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
|---|---|---|---|---|---|---|
| 1 | 25 | 47 | .96 | .96 | .968 | .768 |
| 2 | 41 | 49 | .95 | .92 | .548 | .171 |
| 3 | 35 | 30 | .94 | .90 | .506 | .440 |
| 4 | 32 | 43 | .88 | .77 | .210 | .223 |
| 5 | 12 | 13 | 1.00 | .92 | .146 | .986 |
| 6 | 29 | 34 | .97 | .97 | .866 | .110 |
| 7 | 33 | 47 | .94 | .94 | .752 | .858 |
| 8 | 48 | 56 | .92 | .80 | .096 | .593 |
| 9 | 31 | 33 | .90 | .79 | .147 | .783 |
| 10 | 21 | 28 | .95 | 1.00 | .110 | .970 |
| 11 | 34 | 37 | .65 | .81 | .518 | .414 |
| 12 | 16 | 32 | .69 | .84 | .134 | .111 |
| 13 | 22 | 25 | .91 | .84 | .549 | .730 |
| 14 | 35 | 43 | .97 | .98 | .750 | .849 |
| 15 | 28 | 42 | .96 | .88 | .239 | .442 |
| 16 | 21 | 25 | .71 | .48 | .153 | .400 |
| 17 | 31 | 31 | .52 | .61 | .376 | .869 |
| 18 | 28 | 33 | 1.00 | .97 | .365 | .990 |
| 19 | 17 | 33 | .88 | .91 | .740 | .383 |
| 20 | 28 | 33 | 1.00 | .94 | .194 | .990 |
| 21 | 28 | 30 | .39 | .33 | .869 | .849 |
| 22 | 48 | 56 | .83 | .84 | .952 | .667 |
| 23 | 36 | 46 | .97 | .96 | .920 | .217 |
| 24 | 10 | 18 | 1.00 | 1.00 | 1.000 | 1.000 |
| 25 | 43 | 42 | .81 | .88 | .419 | .847 |

Table 9, cont.

| | | | Proportion Correct | | Improvement $x^2$ p-values | |
|---|---|---|---|---|---|---|
| Item # | $N_f$ | $N_r$ | $f$ | $r$ | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
| 26 | 35 | 52 | .63 | .44 | .139 | .760 |
| 27 | 16 | 14 | 1.00 | .93 | .155 | .985 |
| 28 | 29 | 40 | .93 | .80 | .165 | .963 |
| 29 | 25 | 37 | .92 | .81 | .243 | .859 |
| 30 | 22 | 19 | 1.00 | 1.00 | 1.00 | 1.00 |
| 31 | 19 | 28 | .90 | .93 | .507 | .236 |
| 32 | 20 | 27 | .80 | .85 | .660 | .381 |
| 33 | 32 | 43 | .91 | .81 | .346 | .946 |
| 34 | 41 | 49 | 1.00 | .94 | .059 | .995 |
| 35 | 44 | 43 | 1.00 | .93 | .036 | .995 |
| 36 | 34 | 39 | .97 | .97 | .902 | .555 |
| 37 | 22 | 37 | 1.00 | .89 | .095 | .990 |
| 38 | 32 | 38 | .94 | .95 | .881 | .293 |
| 39 | 28 | 30 | .86 | .80 | .812 | .692 |
| 40 | 32 | 51 | .47 | .51 | .432 | .334 |
| 41 | 28 | 35 | .89 | .86 | .916 | .546 |
| 42 | 35 | 38 | .83 | .76 | .711 | .936 |
| 43 | 17 | 25 | .77 | 1.00 | .001 | .982 |
| 44 | 40 | 45 | .98 | .98 | .656 | .010 |
| 45 | 24 | 32 | 1.00 | .94 | .153 | .993 |
| 46 | 48 | 64 | 1.00 | .97 | .155 | .995 |
| 47 | 19 | 28 | .95 | .97 | .362 | .018 |
| 48 | 45 | 58 | .80 | .78 | .660 | .934 |
| 49 | 22 | 21 | .91 | .95 | .462 | .563 |
| 50 | 42 | 38 | .76 | .79 | .718 | .876 |

Table 9, cont.

| Item # | $N_f$ | $N_r$ | Proportion Correct | | Improvement $x^2$ p-values | |
| | | | f | r | Format Effect (Difficulty) | Format by Score Effect (Discrimination) |
| --- | --- | --- | --- | --- | --- | --- |
| 51 | 30 | 45 | .87 | .98 | .036 | .288 |
| 52 | 16 | 34 | 1.00 | .97 | .480 | 1.000 |
| 53 | 34 | 36 | .88 | .89 | .732 | .865 |
| 54 | 28 | 23 | .75 | .83 | .519 | .362 |
| 55 | 29 | 44 | .69 | .50 | .248 | .877 |
| 56 | 18 | 32 | .94 | .91 | .914 | .082 |
| 57 | 31 | 29 | .55 | .72 | .153 | .582 |
| 58 | 33 | 33 | .61 | .58 | .429 | .591 |
| 59 | 49 | 55 | .53 | .55 | .884 | .954 |
| 60 | 44 | 55 | .84 | .91 | .271 | .133 |
| 61 | 10 | 18 | 1.00 | .83 | .117 | .988 |
| 62 | 43 | 51 | .70 | .65 | .577 | .369 |
| 63 | 12 | 15 | .92 | .53 | .027 | .490 |
| 64 | 34 | 54 | .94 | .80 | .443 | .268 |
| 65 | 16 | 32 | .75 | .69 | .729 | .488 |
| 66 | 28 | 25 | .82 | .88 | .536 | .791 |
| 67 | 29 | 35 | .52 | .40 | .430 | .302 |
| 68 | 33 | 23 | .94 | .87 | .367 | .897 |
| 69 | 26 | 18 | .85 | .89 | .757 | .112 |
| 70 | 28 | 53 | .82 | .76 | .851 | .944 |
| 71 | 16 | 24 | .94 | .83 | .315 | .043 |
| 72 | 20 | 19 | .95 | .90 | .310 | .572 |
| 73 | 23 | 41 | .87 | .73 | .484 | .145 |
| 74 | 23 | 18 | 1.00 | .94 | .032 | .856 |
| 75 | 39 | 51 | .74 | .78 | .321 | .720 |

## APPENDIX

The 3 steps used in the stepwise logistic regression analyses are as follows:

Step 1.   Fit

$$Y_{ij} = \frac{\exp\left[\beta_{oj} + \beta_{1j}X_i + \beta_{2j}M_i + \beta_{3j}M_i{*}X_i\right]}{1 + \exp\left[\beta_{oj} + \beta_{1j}X_i + \beta_{2j}M_i + \beta_{3j}M_i{*}X_i\right]} \quad ,$$

where

$$Y_{ij} = \begin{cases} 1, & \text{if } \underline{i}\text{th examinee answered item } \underline{j} \text{ correctly,} \\ 0, & \text{otherwise,} \end{cases}$$

$$X_i = \underline{i}\text{th examinee's total test score minus } Y_{ij},$$

$$M_i = \begin{cases} +1, & \text{if } \underline{i}\text{th examinee used paper-pencil,} \\ -1, & \text{if } \underline{i}\text{th examinee used computer,} \end{cases}$$

and   Test $G^2(\beta_{oj}, \beta_{1j}, \beta_{2j}, \beta_{3j})$.

Step 2.  Fit

$$Y_{ij} = \frac{\exp\left[\beta_{oj} + \beta_{1j}X_i + \beta_{2j}M_i\right]}{1 + \exp\left[\beta_{oj} + \beta_{1j}X_i + \beta_{2j}M_i\right]} \; ,$$

Test $G^2(\beta_{oj}, \; \beta_{1j}, \; \beta_{2j})$ ,

and

$$G^2(\beta_{oj}, \; \beta_{1j}, \; \beta_{2j}) - G^2(\beta_{oj}, \; \beta_{1j}, \beta_{2j}, \; \beta_{3j}) \; .$$

Step 3.  Fit

$$Y_{ij} = \frac{\exp\left[\beta_{oj} + \beta_{1j}X_i\right]}{1 + \exp\left[\beta_{oj} + \beta_{1j}X_i\right]} \; ,$$

Test $G^2(\beta_{oj}, \; \beta_{1j})$,

and

$$G^2(\beta_{oj}, \; \beta_{1j}) - G^2(\beta_{oj}, \; \beta_{1j}, \; \beta_{2j}) \; .$$
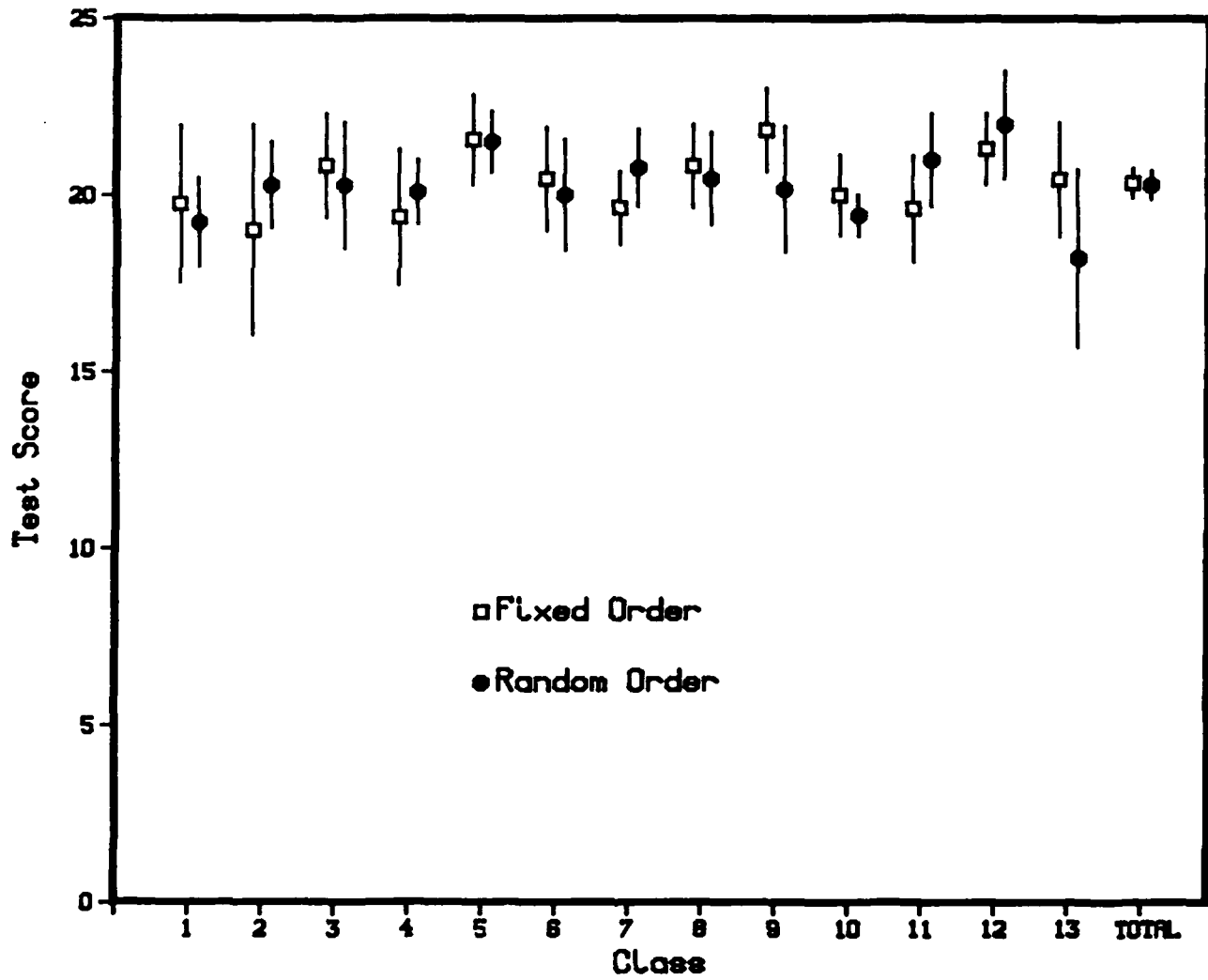
*Figure 1.* The 95% Confidence Interval about the Mean Total Test Score for Both the Pencil & Paper and Computer Groups for Each GRO1 Class.
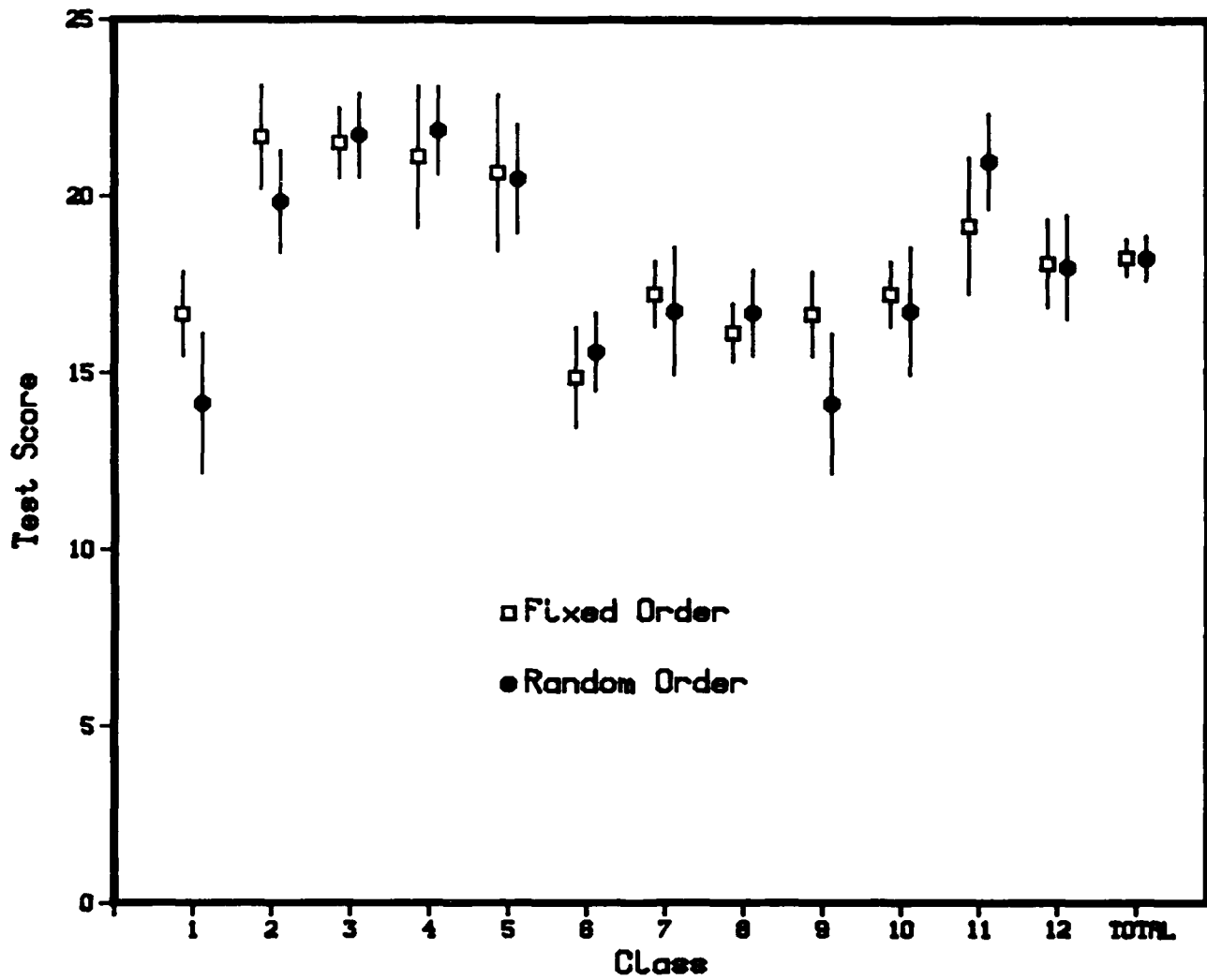
*Figure 2.* The 95% Confidence Interval about the Mean Total Test Score for Both the Pencil & Paper and Computer Groups for Each GRO2 Class.
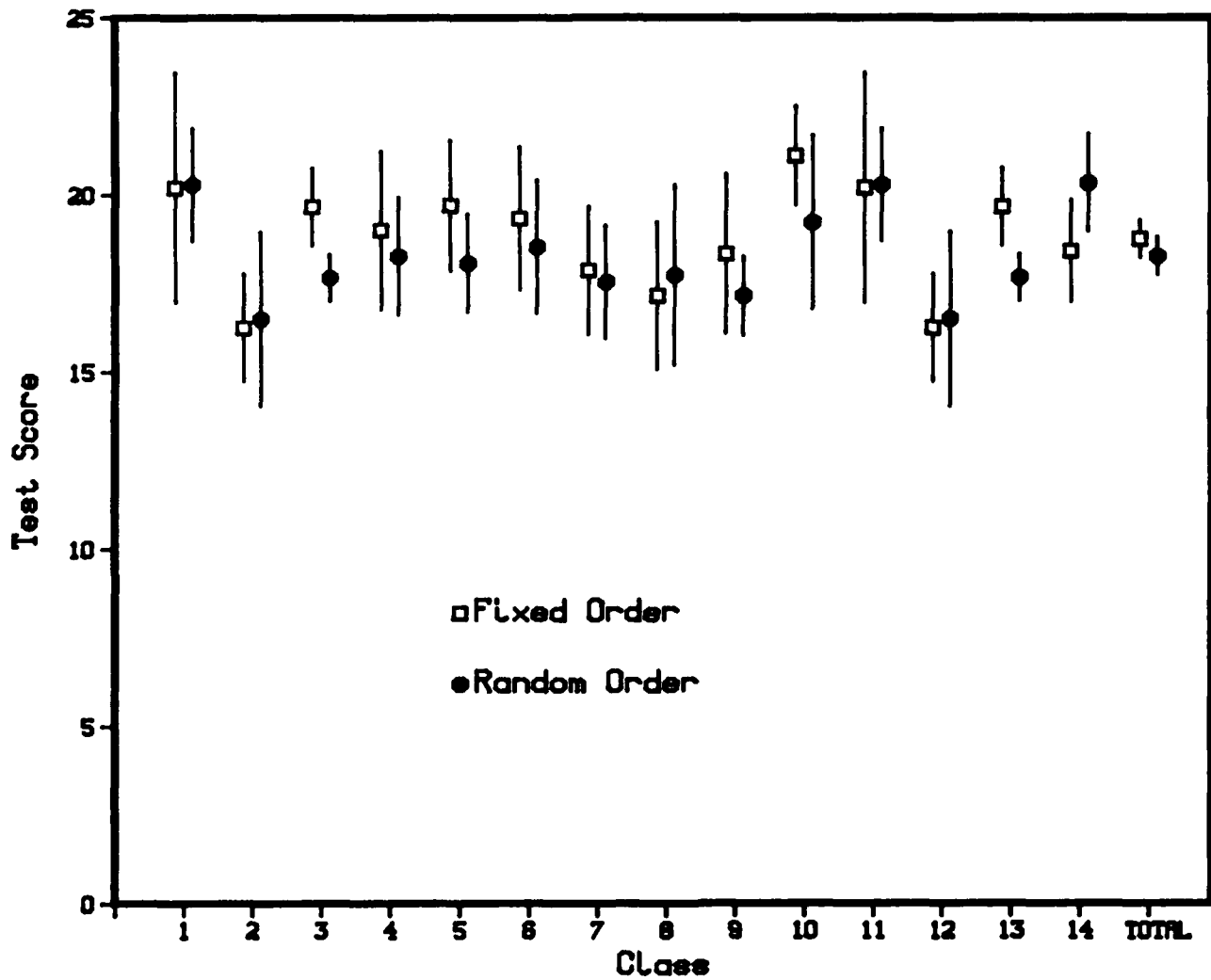
*Figure 3.* The 95% Confidence Interval about the Mean Total Test Score for Both the Pencil & Paper and Computer Groups for Each GRO3 Class.
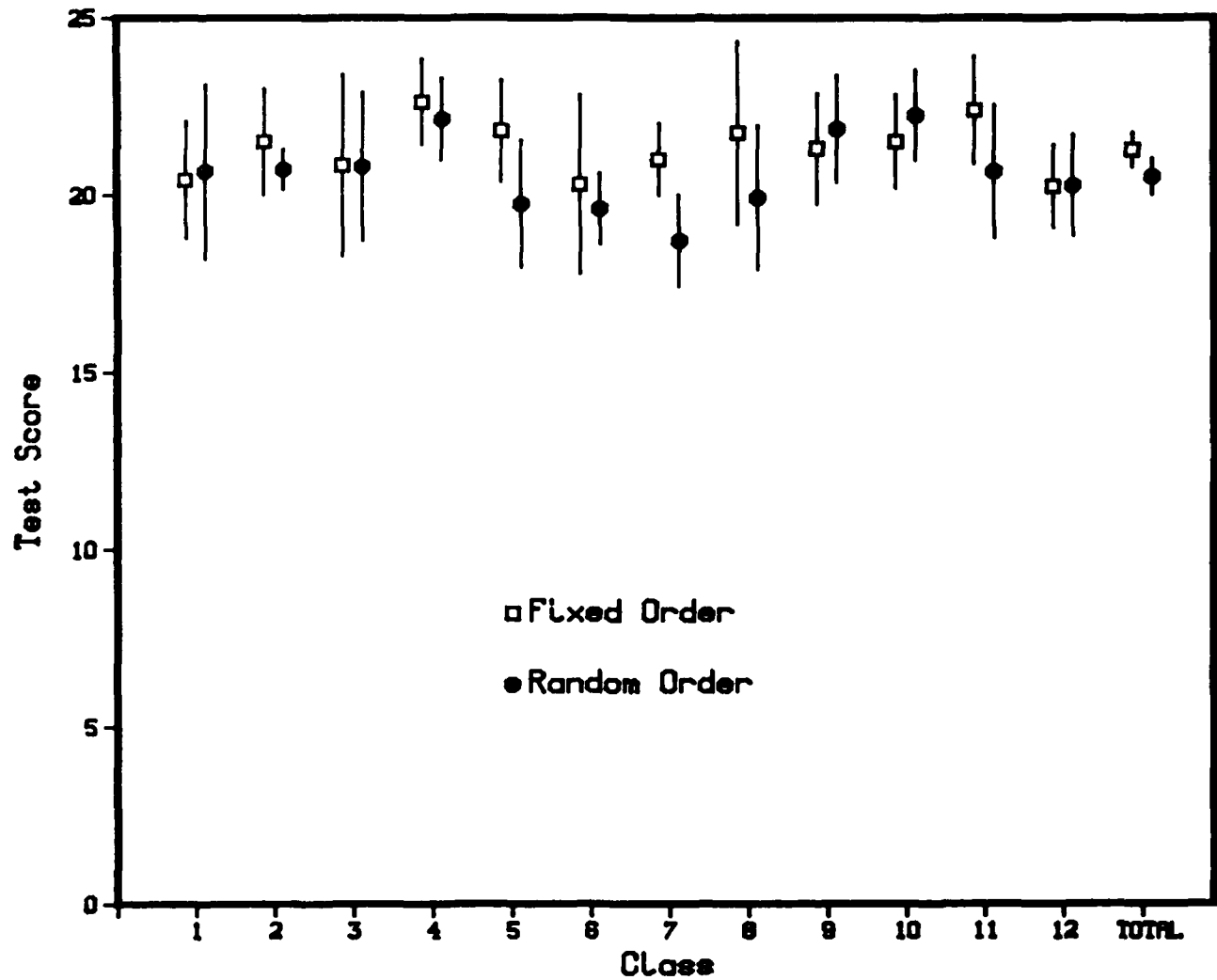
**Figure 4.** The 95% Confidence Interval about the Mean Total Test Score for Both the Pencil & Paper and Computer Groups for Each GRO5 Class.
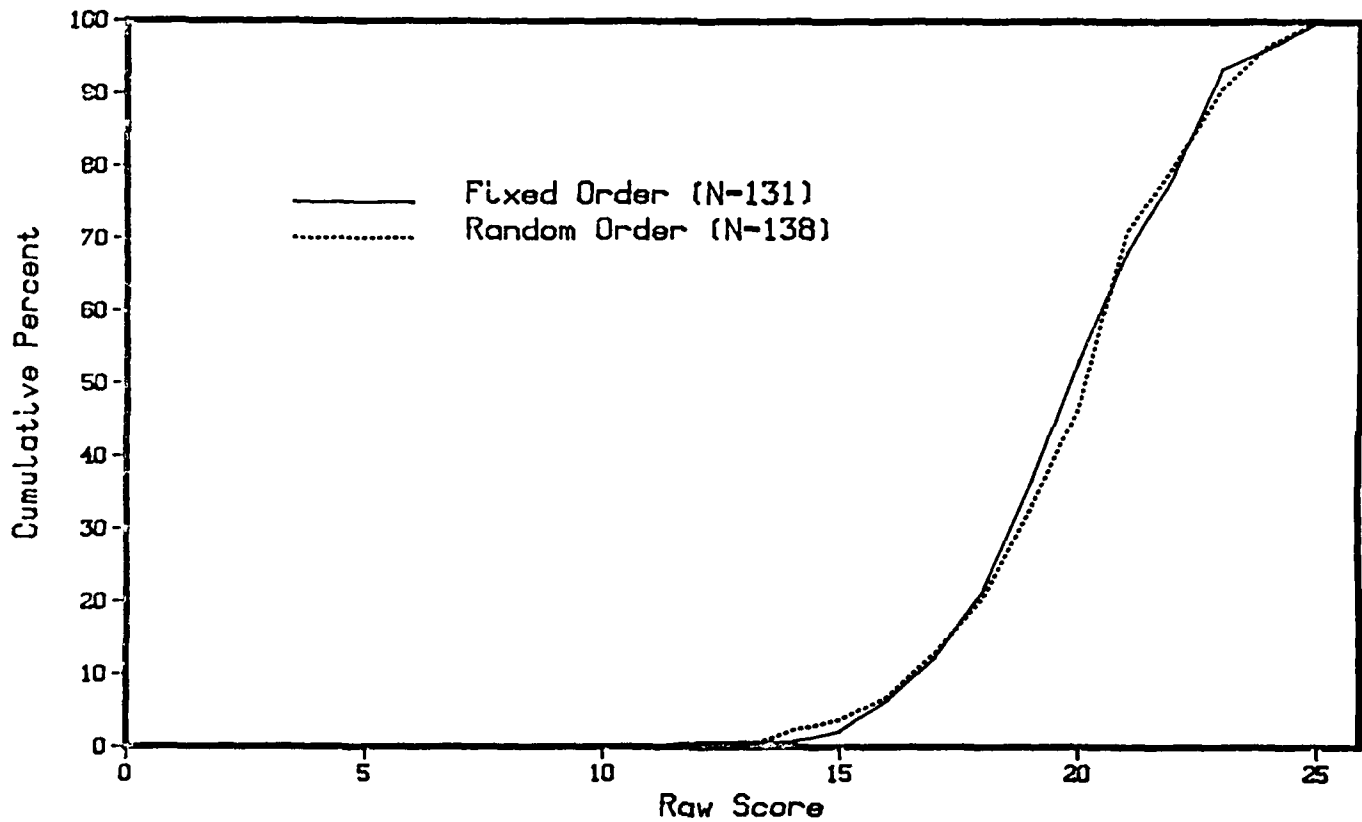
*Figure 5.* Cumulative Frequency Polygons of Total Test Scores for Fixed and Random Order Presentations for Annex GR01.
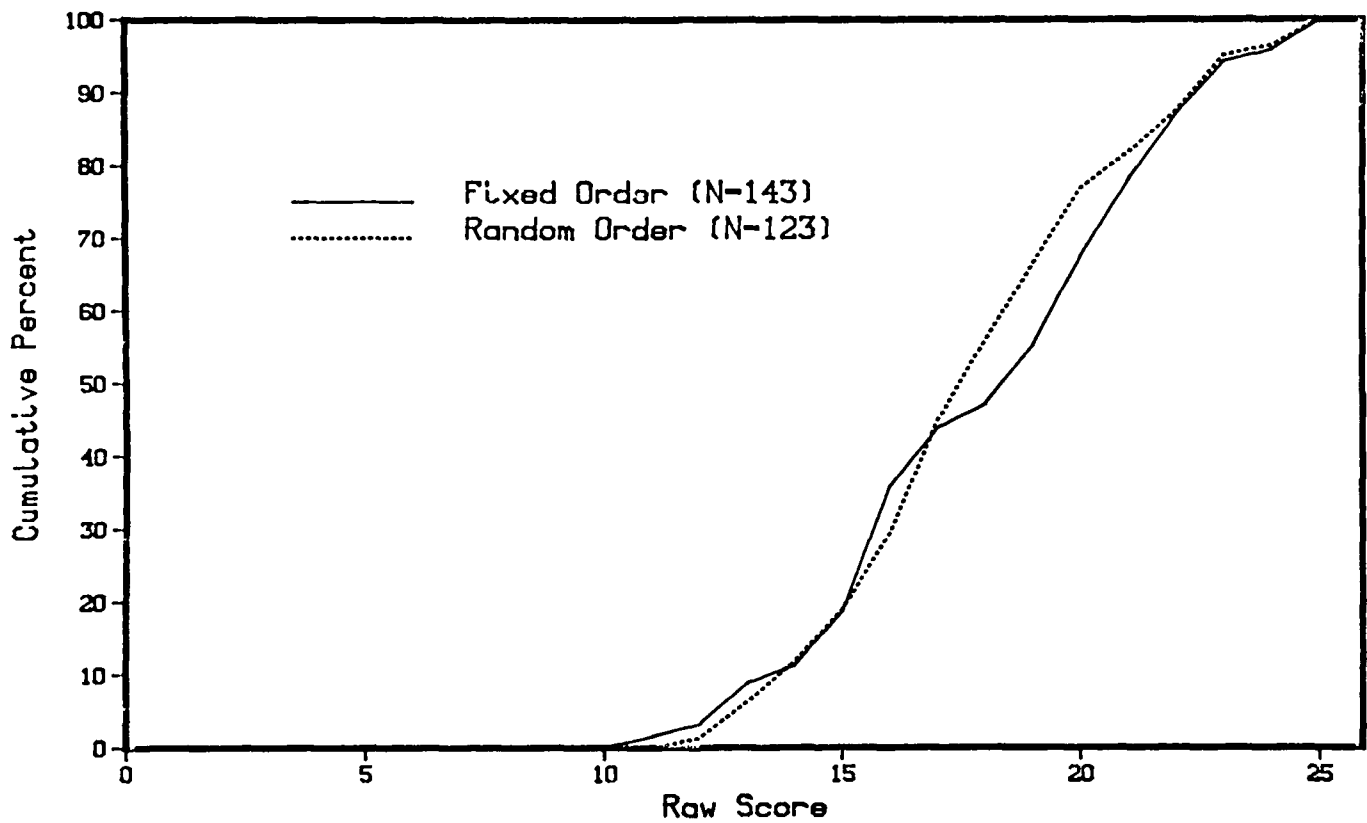
*Figure 6.* Cumulative Frequency Polygons of Total Test Scores for Fixed and
Random Order Presentations for Annex GRO2.
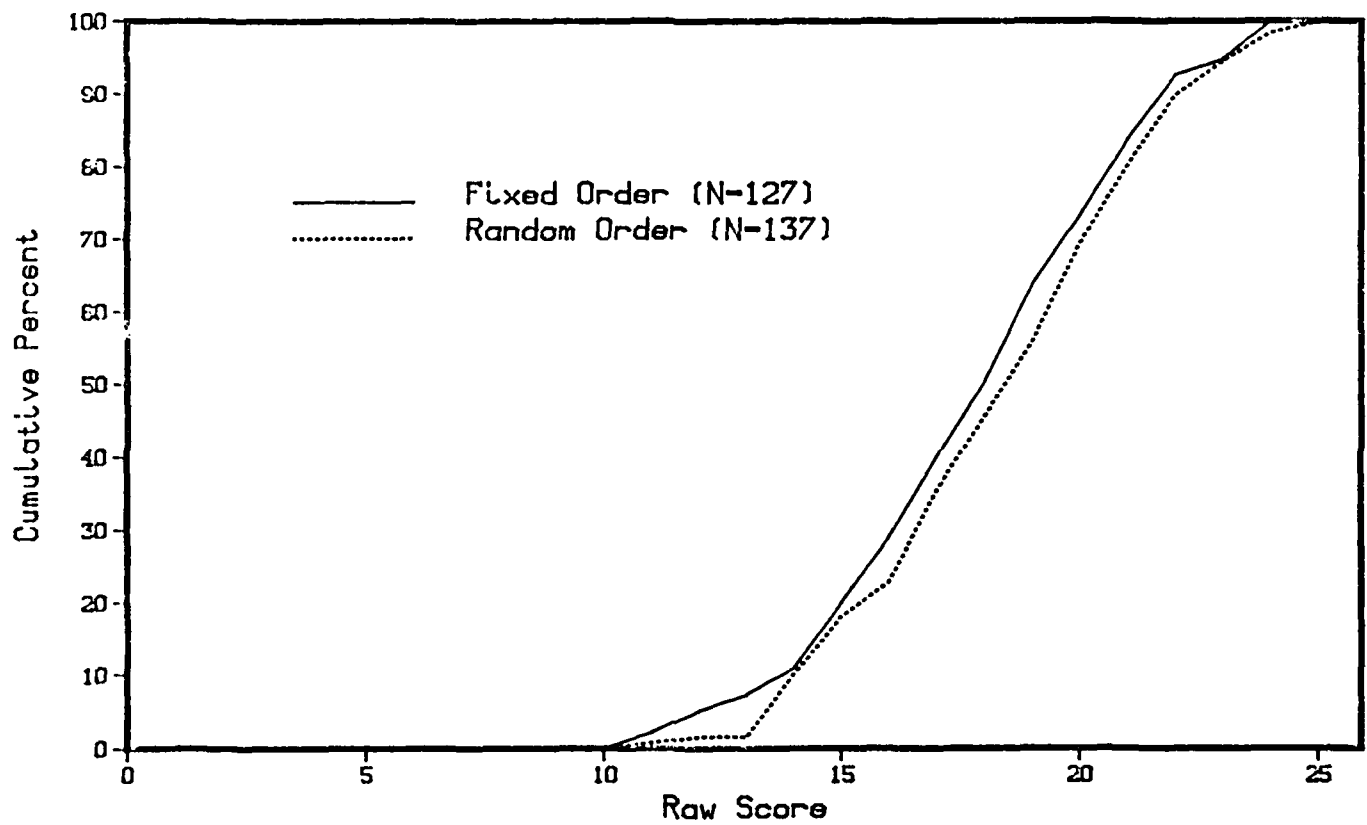
*Figure 7.* Cumulative Frequency Polygons of Total Test Scores for Fixed and Random Order Presentations for Annex GR03.
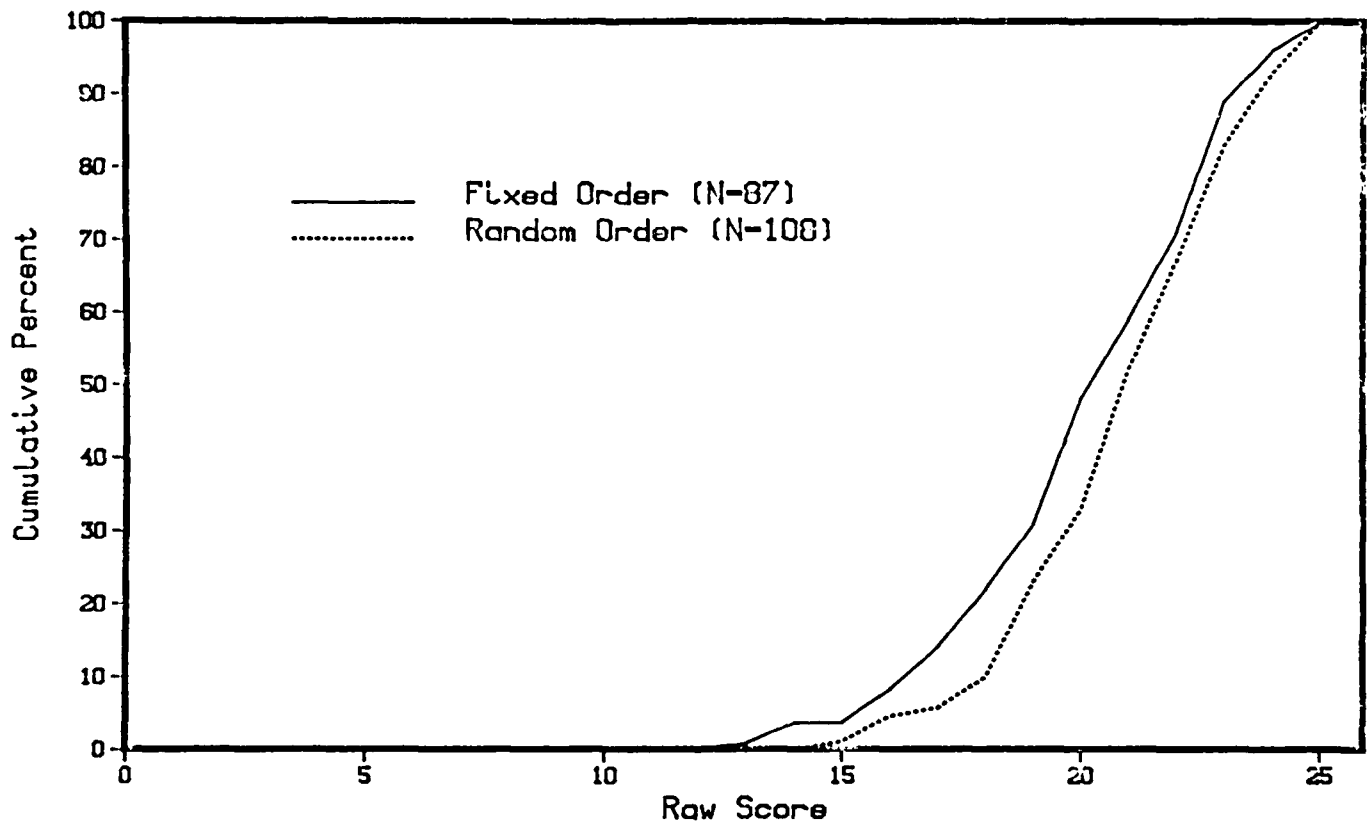
*Figure 8.* Cumulative Frequency Polygons of Total Test Scores for Fixed and Random Order Presentations for Annex GR05.

Dr. Terry Ackerman
American College Testing Programs
P.O. Box 168
Iowa City, IA 52243

Dr. Robert Ahlers
Code N711
Human Factors Laboratory
Naval Training Systems Center
Orlando, FL 32813

Dr. James Algina
University of Florida
Gainesville, FL 32605

Dr. Erling B. Andersen
Department of Statistics
Studiestraede 6
1455 Copenhagen
DENMARK

Dr. Eva L. Baker
UCLA Center for the Study
    of Evaluation
145 Moore Hall
University of California
Los Angeles, CA 90024

Dr. Isaac Bejar
Educational Testing Service
Princeton, NJ 08450

Dr. Menucha Birenbaum
School of Education
Tel Aviv University
Tel Aviv, Ramat Aviv 69978
ISRAEL

Dr. Arthur S. Blaiwes
Code N711
Naval Training Systems Center
Orlando, FL 32813

Dr. Bruce Bloxom
Defense Manpower Data Center
550 Camino El Estero,
    Suite 200
Monterey, CA 93943-3231

Dr. R. Darrell Bock
University of Chicago
NORC
6030 South Ellis
Chicago, IL 60637

Cdt. Arnold Bohrer
Sectie Psychologisch Onderzoek
Rekruterings-En Selectiecentrum
Kwartier Koningen Astrid
Bruijnstraat
1120 Brussels, BELGIUM

Dr. Robert Breaux
Code N-095R
Naval Training Systems Center
Orlando, FL 32813

Dr. Robert Brennan
American College Testing
    Programs
P. O. Box 168
Iowa City, IA 52243

Dr. Lyle D. Broemeling
ONR Code 1111SP
800 North Quincy Street
Arlington, VA 22217

Mr. James W. Carey
Commandant (G-PTE)
U.S. Coast Guard
2100 Second Street, S.W.
Washington, DC 20593

Dr. James Carlson
American College Testing
    Program
P.O. Box 168
Iowa City, IA 52243

Dr. John B. Carroll
409 Elliott Rd.
Chapel Hill, NC 27514

Dr. Robert Carroll
OP 01B7
Washington, DC 20370

Mr. Raymond E. Christal
AFHRL/MOE
Brooks AFB, TX 78235

Dr. Norman Cliff
Department of Psychology
Univ. of So. California
University Park
Los Angeles, CA 90007

Director,
    Manpower Support and
    Readiness Program
Center for Naval Analysis
2000 North Beauregard Street
Alexandria, VA 22311

Dr. Stanley Collyer
Office of Naval Technology
Code 222
800 N. Quincy Street
Arlington, VA 22217-5000

Dr. Hans Crombag
University of Leyden
Education Research Center
Boerhaavelaan 2
2334 EN Leyden
The NETHERLANDS

Dr. Timothy Davey
Educational Testing Service
Princeton, NJ 08541

Dr. C. M. Dayton
Department of Measurement
    Statistics & Evaluation
College of Education
University of Maryland
College Park, MD 20742

Dr. Ralph J. DeAyala
Measurement, Statistics,
    and Evaluation
Benjamin Building
University of Maryland
College Park, MD 20742

Dr. Dattprasad Divgi
Center for Naval Analysis
4401 Ford Avenue
P.O. Box 16268
Alexandria, VA 22302-0268

Dr. Hei-Ki Dong
Bell Communications Research
6 Corporate Place
PYA-1k226
Piscataway, NJ 08854

Dr. Fritz Drasgow
University of Illinois
Department of Psychology
603 E. Daniel St.
Champaign, IL 61820

Defense Technical
    Information Center
Cameron Station, Bldg 5
Alexandria, VA 22314
Attn: TC
(12 Copies)

Dr. Stephen Dunbar
Lindquist Center
    for Measurement
University of Iowa
Iowa City, IA 52242

Dr. James A. Earles
Air Force Human Resources Lab
Brooks AFB, TX 78235

Dr. Kent Eaton
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. John M. Eddins
University of Illinois
252 Engineering Research
    Laboratory
103 South Mathews Street
Urbana, IL 61801

Dr. Susan Embretson
University of Kansas
Psychology Department
426 Fraser
Lawrence, KS 66045

Dr. George Englehard, Jr.
Division of Educational Studies
Emory University
201 Fishburne Bldg.
Atlanta, GA 30322

Dr. Benjamin A. Fairbank
Performance Metrics, Inc.
5825 Callaghan
Suite 225
San Antonio, TX 78228

Dr. Pat Federico
Code 511
NPRDC
San Diego, CA 92152-6800

Dr. Leonard Feldt
Lindquist Center
    for Measurement
University of Iowa
Iowa City, IA 52242

Dr. Richard L. Ferguson
American College Testing
    Program
P.O. Box 168
Iowa City, IA 52240

Dr. Gerhard Fischer
Liebiggasse 5/3
A 1010 Vienna
AUSTRIA

Dr. Myron Fischl
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Prof. Donald Fitzgerald
University of New England
Department of Psychology
Armidale, New South Wales 2351
AUSTRALIA

Mr. Paul Foley
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Alfred R. Fregly
AFOSR/NL
Bolling AFB, DC 20332

Dr. Robert D. Gibbons
Illinois State Psychiatric Inst.
Rm 529W
1601 W. Taylor Street
Chicago, IL 60612

Dr. Janice Gifford
University of Massachusetts
School of Education
Amherst, MA 01003

Dr. Robert Glaser
Learning Research
    & Development Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15260

Dr. Bert Green
Johns Hopkins University
Department of Psychology
Charles & 34th Street
Baltimore, MD 21218

Dipl. Pad. Michael W. Habon
Universitat Dusseldorf
Erziehungswissenschaftliches
Universitatsstr. 1
D-4000 Dusseldorf 1
WEST GERMANY

Dr. Ronald K. Hambleton
Prof. of Education & Psychology
University of Massachusetts
    at Amherst
Hills House
Amherst, MA 01003

Dr. Delwyn Harnisch
University of Illinois
51 Gerty Drive
Champaign, IL 61820

Dr. Grant Henning
Senior Research Scientist
Division of Measurement
    Research and Services
Educational Testing Service
Princeton, NJ 08541

Ms. Rebecca Hetter
Navy Personnel R&D Center
Code 62
San Diego, CA 92152-6800

Dr. Paul W. Holland
Educational Testing Service
Rosedale Road
Princeton, NJ 08541

Prof. Lutz F. Hornke
Institut fur Psychologie
RWTH Aachen
Jaegerstrasse 17/19
D-5100 Aachen
WEST GERMANY

Dr. Paul Horst
677 G Street, #184
Chula Vista, CA 90010

Mr. Dick Hoshaw
OP-135
Arlington Annex
Room 2834
Washington, DC 20350

Dr. Lloyd Humphreys
University of Illinois
Department of Psychology
603 East Daniel Street
Champaign, IL 61820

Dr. Steven Hunka
Department of Education
University of Alberta
Edmonton, Alberta
CANADA

Dr. Huynh Huynh
College of Education
Univ. of South Carolina
Columbia, SC 29208

Dr. Robert Jannarone
Department of Psychology
University of South Carolina
Columbia, SC 29208

Dr. Dennis E. Jennings
Department of Statistics
University of Illinois
1409 West Green Street
Urbana, IL 61801

Dr. Douglas H. Jones
Thatcher Jones Associates
P.O. Box 6640
10 Trafalgar Court
Lawrenceville, NJ    08648

Dr. Milton S. Katz
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Prof. John A. Keats
Department of Psychology
University of Newcastle
N.S.W. 2308
AUSTRALIA

Dr. G. Gage Kingsbury
Portland Public Schools
Research and Evaluation Department
501 North Dixon Street
P. O. Box 3107
Portland, OR 97209-3107

Dr. William Koch
University of Texas-Austin
Measurement and Evaluation
    Center
Austin, TX 78703

Dr. James Kraatz
Computer-based Education
    Research Laboratory
University of Illinois
Urbana, IL 61801

Dr. Leonard Kroeker
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Daryll Lang
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Jerry Lehnus
Defense Manpower Data Center
Suite 400
1600 Wilson Blvd
Rosslyn, VA 22209

Dr. Thomas Leonard
University of Wisconsin
Department of Statistics
1210 West Dayton Street
Madison. WI 53705

Dr. Michael Levine
Educational Psychology
210 Education Bldg.
University of Illinois
Champaign, IL 61801

Dr. Charles Lewis
Educational Testing Service
Princeton, NJ 08541

Dr. Robert Linn
College of Education
University of Illinois
Urbana, IL 61801

Dr. Robert Lockman
Center for Naval Analysis
4401 Ford Avenue
P.O. Box 16268
Alexandria, VA 22302-0268

Dr. Frederic M. Lord
Educational Testing Service
Princeton, NJ 08541

Dr. George B. Macready
Department of Measurement
    Statistics & Evaluation
College of Education
University of Maryland
College Park, MD 20742

Dr. Milton Maier
Center for Naval Analysis
4401 Ford Avenue
P.O. Box 16268
Alexandria, VA 22302-0268

Dr. William L. Maloy
Chief of Naval Education
    and Training
Naval Air Station
Pensacola, FL 32508

Dr. Gary Marco
Stop 31-E
Educational Testing Service
Princeton, NJ 08451

Dr. Clessen Martin
Army Research Institute
5001 Eisenhower Blvd.
Alexandria, VA 22333

Dr. James McBride
Psychological Corporation
c/o Harcourt, Brace,
    Javanovich Inc.
1250 West 6th Street
San Diego, CA 92101

Dr. Clarence McCormick
HQ, MEPCOM
MEPCT-P
2500 Green Bav Road
North Chicago, IL 60064

Dr. Robert McKinley
Educational Testing Service
20-P
Princeton, NJ 08541

Dr. James McMichael
Technical Director
Navy Personnel R&D Center
San Diego, CA 92152

Dr. Barbara Means
Human Resources
    Research Organization
1100 South Washington
Alexandria, VA 22314

Dr. Robert Mislevy
Educational Testing Service
Princeton, NJ 08541

Dr. William Montague
NPRDC Code 13
San Diego, CA 92152-6800

Ms. Kathleen Moreno
Navy Personnel R&D Center
Code 62
San Diego, CA 92152-6800

Headquarters, Marine Corps
Code MPI-20
Washington, DC 20380

Dr. W. Alan Nicewander
University of Oklahoma
Department of Psychology
Oklahoma City, OK 73069

Deputy Technical Director
NPRDC Code 01A
San Diego, CA    92152-6800

Director, Training Laboratory,
    NPRDC (Code 05)
San Diego, CA 92152-6800

Director, Manpower and Personnel
    Laboratory,
    NPRDC (Code 06)
San Diego, CA 92152-6800

Director, Human Factors
    & Organizational Systems Lab,
    NPRDC (Code 07)
San Diego, CA 92152-6800

Fleet Support Office,
    NPRDC (Code 301)
San Diego, CA 92152-6800

Library, NPRDC
Code P201L
San Diego, CA 92152-6800

Commanding Officer,
    Naval Research Laboratory
Code 2627
Washington, DC 20390

Dr. Harold F. O'Neil, Jr.
School of Education - WPH 801
Department of Educational
    Psychology & Technology
University of Southern California
Los Angeles, CA    90089-0031

Dr. James Olson
WICAT, Inc.
1875 South State Street
Orem, UT 84057

Office of Naval Research,
    Code 1142CS
800 N. Quincy Street
Arlington, VA 22217-5000
(6 Copies)

Office of Naval Research,
    Code 125
300 N. Quincy Street
Arlington, VA    22217-5000

Assistant for MPT Research,
    Development and Studies
    OP 01B7
Washington, DC 20370

Dr. Judith Orasanu
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Jesse Orlansky
Institute for Defense Analyses
1801 N. Beauregard St.
Alexandria, VA 22311

Dr. Randolph Park
Army Research Institute
5001 Eisenhower Blvd.
Alexandria, VA 22333

Wayne M. Patience
American Council on Education
GED Testing Service, Suite 20
One Dupont Circle, NW
Washington, DC 20036

Dr. James Paulson
Department of Psychology
Portland State University
P.O. Box 751
Portland, OR 97207

Administrative Sciences Department,
    Naval Postgraduate School
Monterey, CA 93940

Department of Operations Research,
    Naval Postgraduate School
Monterey, CA 93940

Dr. Mark D. Reckase
ACT
P. O. Box 168
Iowa City, IA 52243

Dr. Malcolm Rea
AFHRL/MP
Brooks AFB, TX 78235

Dr. Barry Riegelhaupt
HumRRO
1100 South Washington Street
Alexandria, VA 22314

Dr. Carl Ross
CNET-PDCD
Building 90
Great Lakes NTC, IL 60088

Dr. J. Ryan
Department of Education
University of South Carolina
Columbia, SC 29208

Dr. Fumiko Samejima
Department of Psychology
University of Tennessee
3108 AustinPeay Bldg.
Knoxville, TN 37916-0900

Mr. Drew Sands
NPRDC Code 62
San Diego, CA 92152-6800

Lowell Schoer
Psychological & Quantitative
    Foundations
College of Education
University of Iowa
Iowa City, IA 52242

Dr. Mary Schratz
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Dan Segall
Navy Personnel R&D Center
San Diego, CA 92152

Dr. W. Steve Sellman
OASD(MRA&L)
2B269 The Pentagon
Washington, DC 20301

Dr. Kazuo Shigemasu
7-9-24 Kugenuma-Kaigan
Fujusawa 251
JAPAN

Dr. William Sims
Center for Naval Analysis
4401 Ford Avenue
P.O. Box 16268
Alexandria, VA 22302-0268

Dr. H. Wallace Sinaiko
Manpower Research
    and Advisory Services
Smithsonian Institution
801 North Pitt Street
Alexandria, VA 22314

Dr. Richard E. Snow
Department of Psychology
Stanford University
Stanford, CA   94306

Dr. Richard Sorensen
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Paul Speckman
University of Missouri
Department of Statistics
Columbia, MO 65201

Dr. Judy Spray
ACT
P.O. Box 168
Iowa City, IA 52243

Dr. Martha Stocking
Educational Testing Service
Princeton, NJ 08541

Dr. Peter Stoloff
Center for Naval Analysis
200 North Beauregard Street
Alexandria, VA 22311

Dr. William Stout
University of Illinois
Department of Statistics
101 Illini Hall
725 South Wright St.
Champaign, IL 61820

Dr. Hariharan Swaminathan
Laboratory of Psychometric and
    Evaluation Research
School of Education
University of Massachusetts
Amherst, MA 01003

Mr. Brad Sympson
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. John Tangney
AFOSR/NL
Bolling AFB, DC 20332

Dr. Kikumi Tatsuoka
CERL
252 Engineering Research
    Laboratory
Urbana, IL 61801

Dr. Maurice Tatsuoka
220 Education Bldg
1310 S. Sixth St.
Champaign, IL 61820

Dr. David Thissen
Department of Psychology
University of Kansas
Lawrence, KS 66044

Mr. Gary Thomasson
University of Illinois
Educational Psychology
Champaign, IL 61820

Dr. Robert Tsutakawa
University of Missouri
Department of Statistics
222 Math. Sciences Bldg.
Columbia, MO    65211

Dr. Ledyard Tucker
University of Illinois
Department of Psychology
603 E. Daniel Street
Champaign, IL 61820

Dr. Vern W. Urry
Personnel R&D Center
Office of Personnel Management
1900 E. Street, NW
Washington, DC 20415

Dr. David Vale
Assessment Systems Corp.
2233 University Avenue
Suite 310
St. Paul, MN 55114

Dr. Frank Vicino
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Howard Wainer
Division of Psychological Studies
Educational Testing Service
Princeton, NJ 08541

Dr. Ming-Mei Wang
Lindquist Center
    for Measurement
University of Iowa
Iowa City, IA 52242

Dr. Thomas A. Warm
Coast Guard Institute
P. O. Substation 18
Oklahoma City, OK 73169

Dr. Brian Waters
Program Manager
Manpower Analysis Program
HumRRO
1100 S. Washington St.
Alexandria, VA 22314

Dr. David J. Weiss
N660 Elliott Hall
University of Minnesota
75 E. River Road
Minneapolis, MN 55455

Dr. Ronald A. Weitzman
NPS, Code 54Wz
Monterey, CA 92152-6800

Major John Welsh
AFHRL/MOAN
Brooks AFB, TX 78223

Dr. Douglas Wetzel
Code 12
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Rand R. Wilcox
University of Southern
    California
Department of Psychology
Los Angeles, CA 90007

German Military Representative
ATTN: Wolfgang Wildegrube
    Streitkraefteamt
    D-5300 Bonn 2
4000 Brandywine Street, NW
Washington, DC 20016

Dr. Bruce Williams
Department of Educational
    Psychology
University of Illinois
Urbana, IL 61801

Dr. Hilda Wing
NRC GF-176
2101 Constitution Ave
Washington, DC 20418

Dr. Martin F. Wiskoff
Navy Personnel R & D Center
San Diego, CA 92152-6800

Mr. John H. Wolfe
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. George Wong
Biostatistics Laboratory
Memorial Sloan-Kettering
    Cancer Center
1275 York Avenue
New York, NY 10021

Dr. Wallace Wulfeck, III
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Kentaro Yamamoto
Educational Testing Service
Rosedale Road
Princeton, NJ 08541

Dr. Wendy Yen
CTB/McGraw Hill
Del Monte Research Park
Monterey, CA 93940

Dr. Joseph L. Young
Memory & Cognitive
    Processes
National Science Foundation
Washington, DC 20550

Dr. Anthony R. Zara
National Council of State
    Boards of Nursing, Inc.
625 North Michigan Ave.
Suite 1544
Chicago, IL 60611