

A Computerized Version of the Coloured Progressive Matrices

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The increasing availability of computer technology and its successful application in educational and rehabilitation settings has stimulated clinical investigators and speech and language pathologists to consider how this technology can be utilized to serve aphasic adults. Computer-assisted assessment is an area relatively unexplored but very promising for microcomputer application. Collection of scores, reaction times, and error analysis, as well as data analysis are tasks efficiently handled by computer.

We had three purposes in designing this study:

1. To demonstrate the design and computer implementation of a common test for brain damage.
2. To evaluate computerized assessment and concomitant concerns such as the man-machine or human-computer interaction.
3. To determine whether the power of computerized error analysis could help us differentiate among three groups of aphasic patients: those with anterior lesions, those with posterior lesions, and globally aphasic patients.

DESCRIPTION OF COMPUTER IMPLEMENTATION OF THE TEST

The Coloured Progressive Matrices (CPM) (Raven, 1948) was selected as the test instrument because it is a basic tool in many aphasia test batteries and its standard administration is highly compatible with computerized presentation. Also, we felt the computer could easily capture performance information usually ignored in hand-scored tests. For instance, error patterns are rarely analyzed because the process is tedious and time-consuming. However, error patterns may differ across aphasic individuals with different lesion sites. This information may contribute to a better understanding of brain-behavior relationships.

This computerized version was implemented on an IBM-PC with 576 kilobytes of random access memory, a Tecmar color board, dual disk drives, a standard keyboard, a TSD touch sensitive screen mounted on a RGB monitor and a printer. The program was written in the PC/FORTH language.

We attempted to replicate the conventional administration of the CPM exactly, but a few modifications were necessary. Practice items were designed and included to familiarize the subject with the operation of the touch screen, the computerized test and task requirements. One of the four practice items is illustrated in Figure 1. It was necessary to modify the graphics in some of the original test items because smooth diagonal lines cannot be drawn on a screen comprised of rectangular pixels. Thus, some of the original CPM items appear slightly different. The only item actually altered was the last item in Test A. Figure 2 shows the modified version which includes three

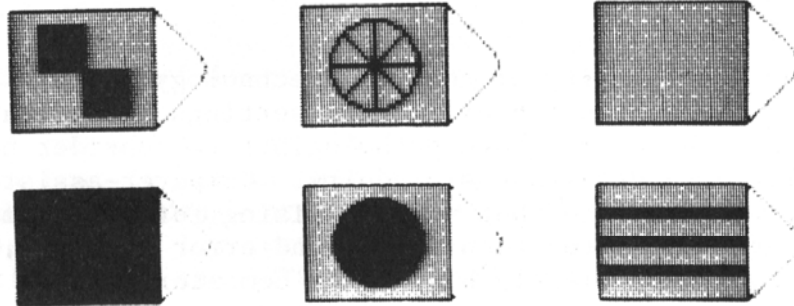
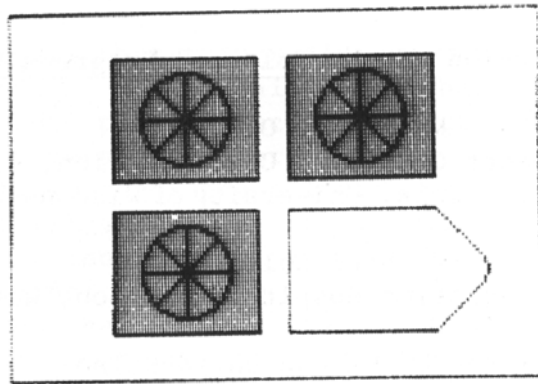


Figure 1. One of the four practice items created for the computerized version of the CPM.

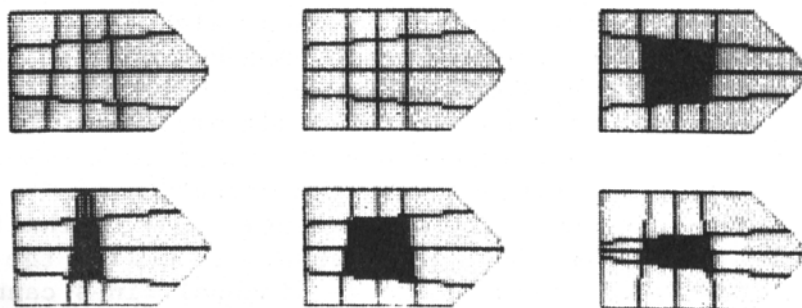
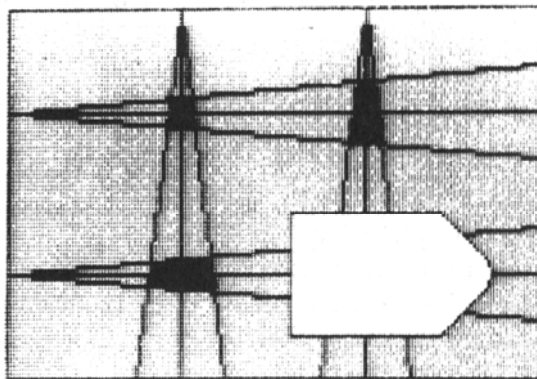


Figure 2. CPM Subtest A, Number 12, as modified for computer presentation.

diagonal lines instead of the original seven. We found that when an exact replication of the original item was drawn on the screen, the entire design increased considerably in difficulty.

The computerized test can be administered in either of two modes: computer-controlled or patient-controlled. In the computer-controlled mode, after the practice items, the test can proceed independently of clinician intervention. The only requirement is that the patient touch the screen in the appropriate location to register the response. Default timing values ensure that uniform amounts of time are available for a response, for any self-corrections, and for presentation of each successive test item. Timing determinations were empirically determined. After a page is presented by the computer, the patient has five minutes in which to make his first touch response; after this initial touch, there is a 15-second period for post-response evaluation and any changes. If no changes are made, the page is erased and a blank screen is presented for 3 seconds. A new page is automatically presented. If a change is made, another 15-second period follows for response evaluation and an additional change. There is no limit on the number of self-corrections that can be made.

In the patient-controlled mode, the patient actively controls the speed with which each test item is presented. This "page turning" is accomplished by pushing a button to advance to the next page as soon as a response is made.

The clinician can intervene in either mode to increase the amount of time in which a first or self-corrected response is made or to decrease the amount of time after a final response is made.

As mentioned above, more than one response per page is permitted. The computer records the last five responses; the final response given is the one scored. The test can be terminated before reaching the final page. If a patient fails to make a response for three pages in succession, the test is automatically stopped by the computer. The clinician can stop the test at any time and save or discard data to that point.

A significant advantage of this computerized version over its conventional counterpart is the automatic retrieval of detailed response information. Score and percentile information, using Wertz and Lemme's norms (Wertz and Lemme, 1974), is immediately available. Timing information, including response time per item, per subtest and for the entire test, is also provided.

Of major potential value is the computer's provision of error type analyses and tabulation of the problem types on which errors occurred. The error types used in this study were based on those described by Horner and Nailling (1980).

- a= Difference: The piece has no figure of any kind on it; the figure shown is irrelevant.
- b= Inadequate Individuation: The figure is contaminated by irrelevancies or distortions; it combines figure irrelevantly; it is the whole or half the pattern to be completed.
- c= Repetition of the pattern: Above and to the left, immediately above or immediately to the left of the space to be filled.
- d= Incomplete correlate: The figure is wrongly oriented; it is incomplete, but correct as far as it goes.
- x= Correct choice: It completes the pattern both horizontally and vertically.

For instance, in CPM subtest A, item 11 (Figure 3), answers 1 and 3 are considered type "d" errors: i.e. incomplete correlates of the target. Answers 2 and 5 are considered type "c" errors: repetitions of the pattern. Answer 6 is a type "a" error: a clear difference from the target pattern.

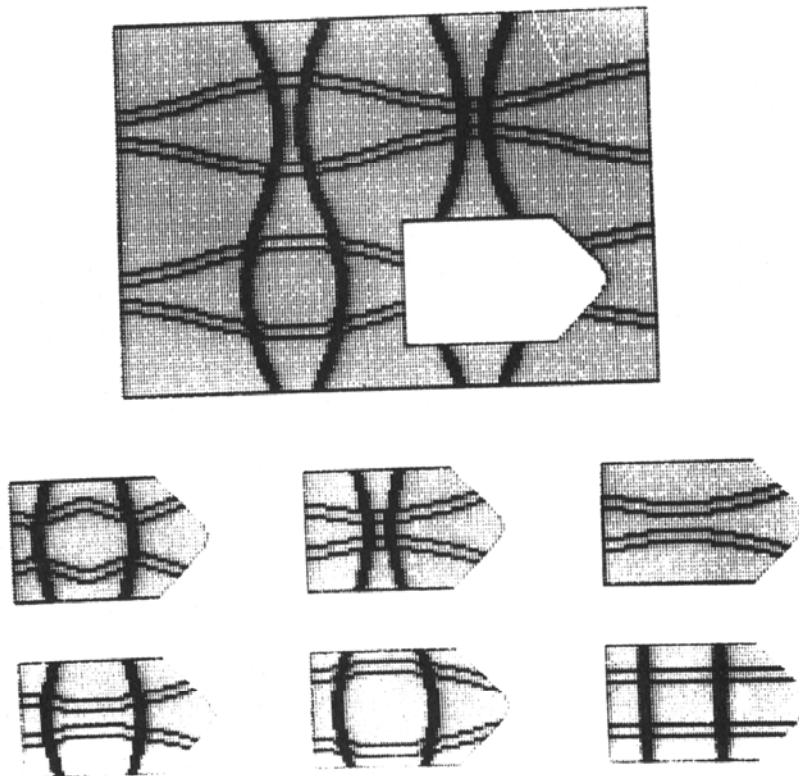


Figure 3. Item 11 from Subtest A of the CPM as it appears in the computerized version of the CPM.

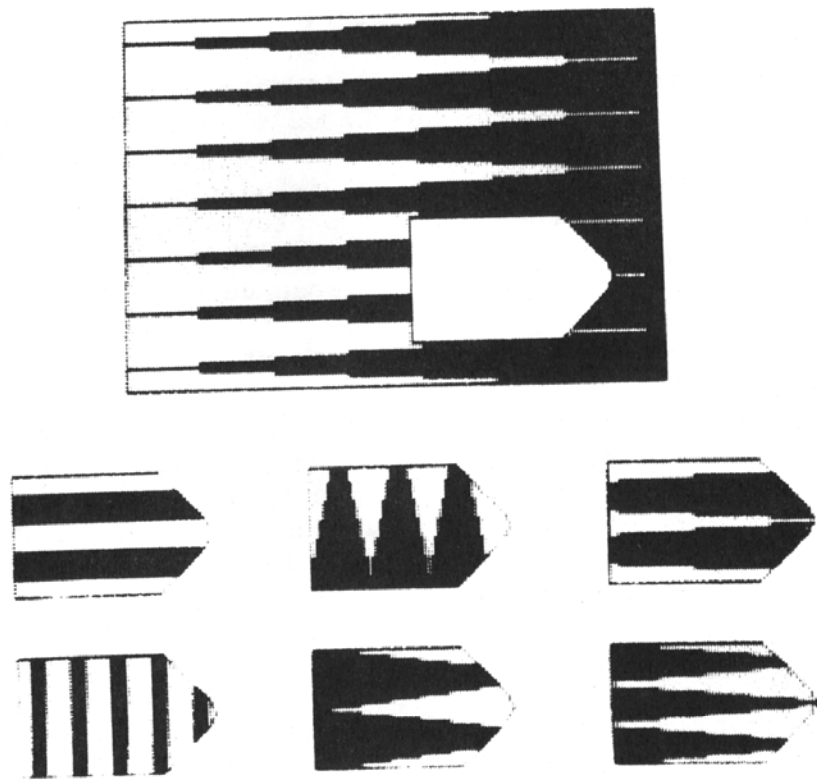


Figure 4. Item 10 from Subtest A of the CPM as it appears in the computerized version of the CPM.

The CPM tests four types of visual reasoning skills described by Horner and Nailling (1980).

- (1) Continuity and reconstruction of simple and complex structures.
- (2) Discrete pattern completions.
- (3) Reasoning by analogy.
- (4) Simple continuous pattern completions.

In subtest A, item 10 (Figure 4) represents problem type 1. The task requires the subject to discern continuity in a complex state.

The frequency with which errors occur on particular problem types may be a guide to residual abstract visual problem solving skills.

COMPARISON OF CPM PERFORMANCE ACROSS THREE TEST CONDITIONS

Method

Subjects. Subjects were 16 aphasic individuals. Five subjects were aphasic patients with anterior lesions, seven were patients with posterior lesions, and four were globally aphasic. They were selected on the basis of the following criteria: 1) evidence from the medical records of a single, unilateral cerebral lesion; 2) site of lesion confirmed by CT scan, brain scan, EEG or neurologic evaluation; 3) minimum of three months post onset of brain disease; 4) no sensory or motor impairments (corrected or uncorrected) that would interfere with test performance.

Tests. Each subject was administered the computerized version of the CPM in two conditions. In one the subject controlled the speed of "page turning." We called this the button condition because the patient controlled the page turning button. The other condition, in which the computer controlled the speed of page turning, was referred to as the no button condition. The two conditions were presented within two weeks of each other. The performance of each subject on both computerized versions was compared with his performance on the CPM administered in the traditional fashion. With one exception, the standard format of the CPM was administered within 60 days of the experimental conditions.

Descriptive analysis was employed to evaluate and compare test performances. The following parameters of test performance were studied; total score, reaction time prior to each response, pattern of error type, types of problems on which errors occurred, and numbers of self-corrections.

Results. Accuracy of performance did not differ substantially among the three conditions of presentation (computer-controlled, patient-controlled or noncomputerized) when comparisons were based on mean scores. As illustrated in Figure 5, performance was comparable across conditions for each group. Note that, because of missing data points in the standard testing version, we were unable to make a comparison in the global group between the standard version and either computerized version. For the two patients on whom all data was collected, total score is essentially identical across the 3 conditions. For all four global patients, total score in both computerized versions is nearly identical, as is shown in the bar graph.

We could not detect a trend toward better performance by a group on a given condition. Across all conditions, posterior patients were more accurate than anterior patients, and both these groups were more accurate than global patients.

A comparison of total reaction times for each computerized version revealed no substantial differences between conditions for any group (Figure 6). In addition, mean RT's were quite similar across all groups.

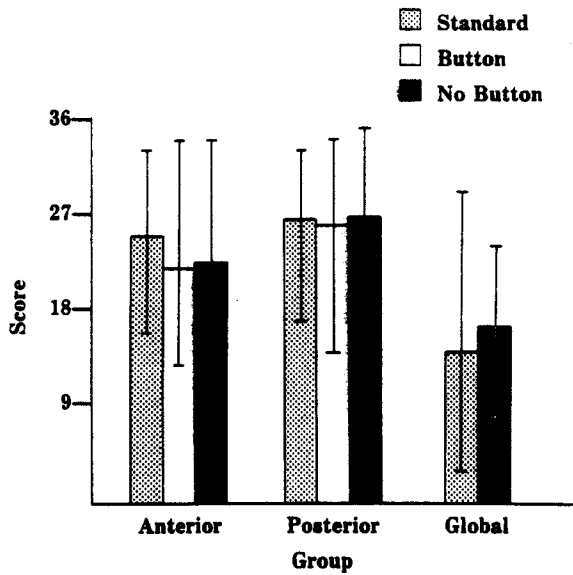


Figure 5. Scores of Anterior, Posterior, and Global groups in Standard, Button, and No Button conditions.

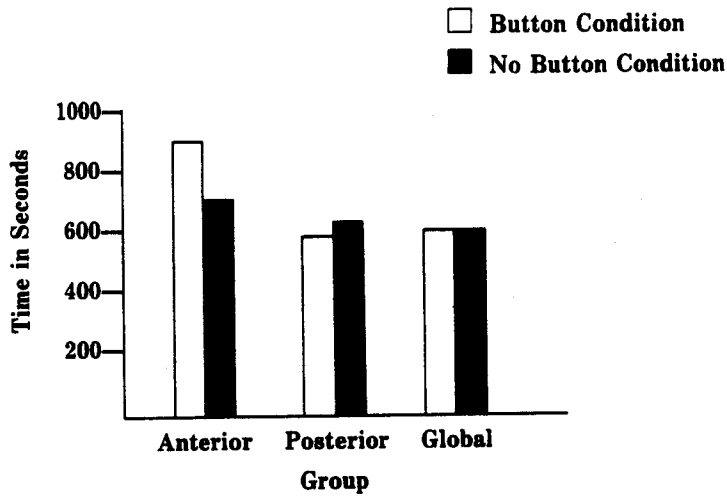


Figure 6. Total reaction times for Anterior, Posterior and Global groups in Button and No Button Condition.

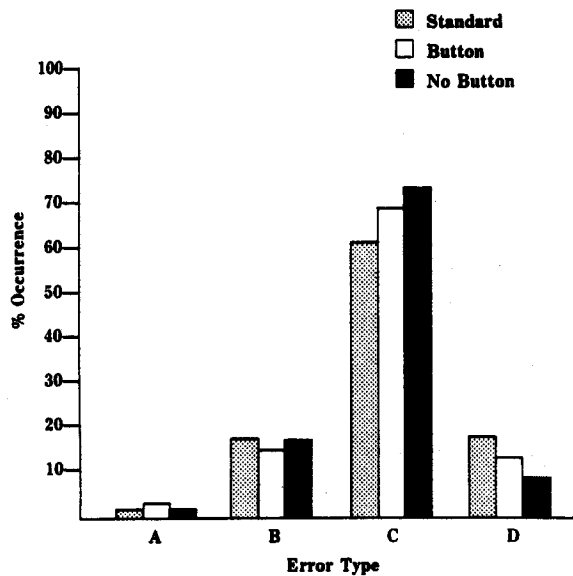


Figure 7. Percent occurrence of four error types for Standard Button, and No Button conditions for the Anterior group.

An analysis of error type failed to reveal any substantial differences among computerized versions for any group (Figures 7, 8 and 9 for the anterior, posterior and global groups respectively). Type "C" errors predominated for all three groups, that is a repetition of the pattern was selected. Type "A" errors, in which a different pattern was selected, were the least frequent.

Analysis of performance by problem type revealed that all our patients were far more likely to commit errors of problem type 1 (that is, continuity and reconstruction of simple and complex structures) than any other type regardless of condition (Figures 10, 11 and 12 for the anterior, posterior and global groups, respectively).

The mean number of self-corrections in either computerized version were small for each group. As is illustrated in Figure 13, all groups made more self-corrections in the no-button, or computer-controlled condition.

Conclusions. There were no substantial quantitative differences among conditions for any group. For each group, there were no substantial qualitative differences among conditions in terms of reaction time, error type or problem type. More self-corrections were made in the computer-controlled condition by all groups.

These results demonstrate that either computerized version of the CPM is essentially equivalent to the conventional form of administration. The real advantage of the computerized versions is the ease and efficiency of data collection. It may also be that computer-assisted testing and treatment reduces the subject's anxiety by allowing him to partially control the test situation and to commit errors without clinician observation.

The lack of differences among conditions indicates that the computerized versions did not present greater cognitive load and did not change the demands on visual processing or acuity. Patient control of the button did not appear to place extra processing demands on the individual.

There were few differences among aphasic groups on any of the parameters we studied. This seems to be consistent with the conviction, held by many, that aphasic subgroups do not differ fundamentally in resources available to perform tests of nonverbal reasoning.

In our experience with this study, we did encounter some practical difficulties. On occasion, we found that patients would strike the "next page" button when they had intended to touch the screen for a response. As is seen during performance of the standard CPM, patients were observed to touch the large rectangle at the top of the screen rather than one of the six possible answers. In the computer-controlled condition, some patients required more time than the 15 seconds allowed for post-response analysis and self-correction, requiring clinician intervention. Some patients apparently felt constrained by the mechanization and had to be encouraged to make self-corrections.

These problems lead us to believe that it may be necessary for the clinician to oversee the computer-administered testing to prevent the occurrence of these difficulties. Despite the clinician time required to oversee testing, we feel that the ease of data collection and analysis offset that relatively minor objection and that computer administration of the CPM is a useful alternative to traditional administration.

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- Horner, J. and Nailling, K. Raven's Coloured Progressive Matrices: Interpreting results through analysis of problem type and error type. In R. Brookshire (Ed.), Clinical Aphasiology: Conference Proceedings, 1980. Minneapolis, MN: BRK Publishers, 1980.

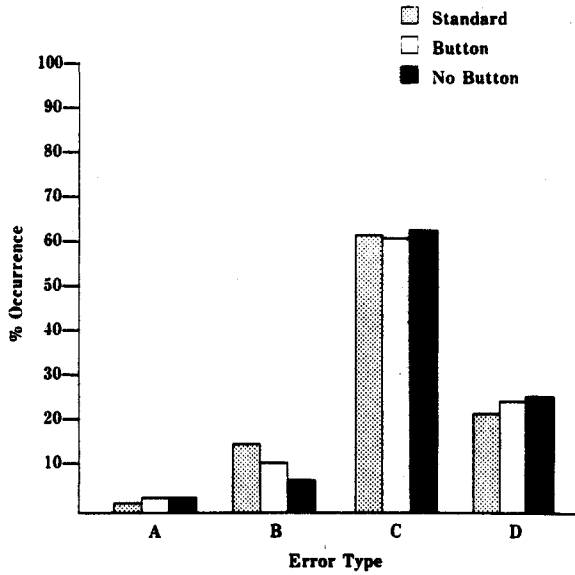


Figure 8. Percent occurrence of four error types for Standard, Button, and No Button conditions for the Posterior group.

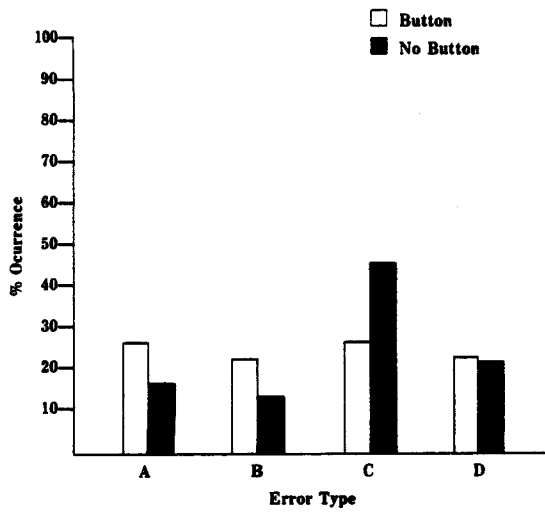


Figure 9. Percent occurrence of four error types for Standard, Button, and No Button conditions for the Global group.

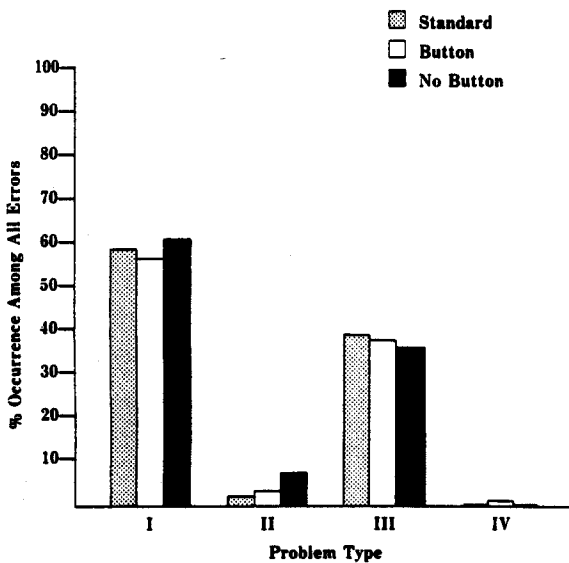


Figure 10. Percent errors according to problem type for Standard, Button, and No Button conditions for the Anterior group.

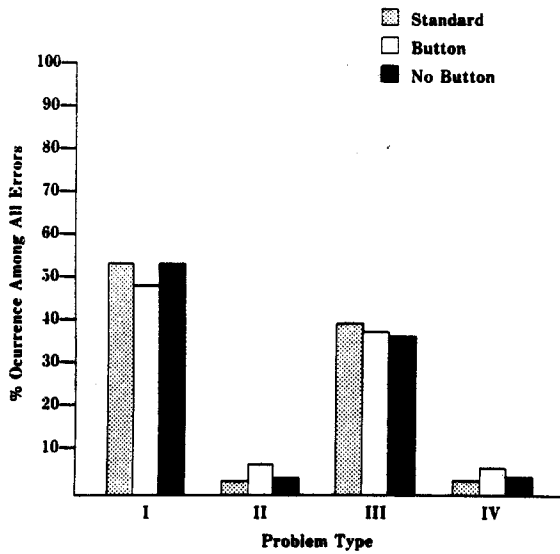


Figure 11. Percent errors according to problem type for Standard, Button, and No Button conditions for the Posterior group.

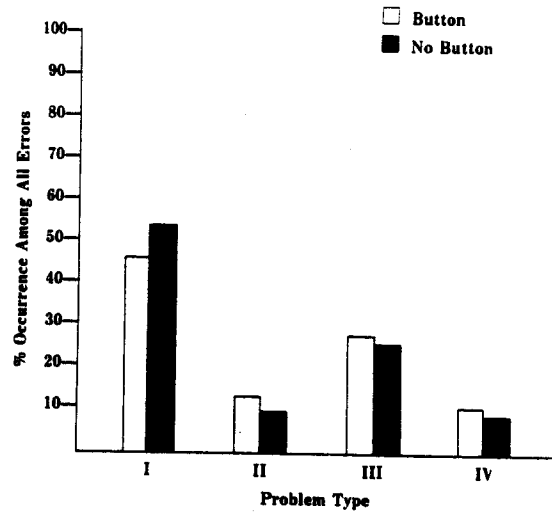


Figure 12. Percent errors according to problem type for Standard, Button, and No Button conditions for the Global group.

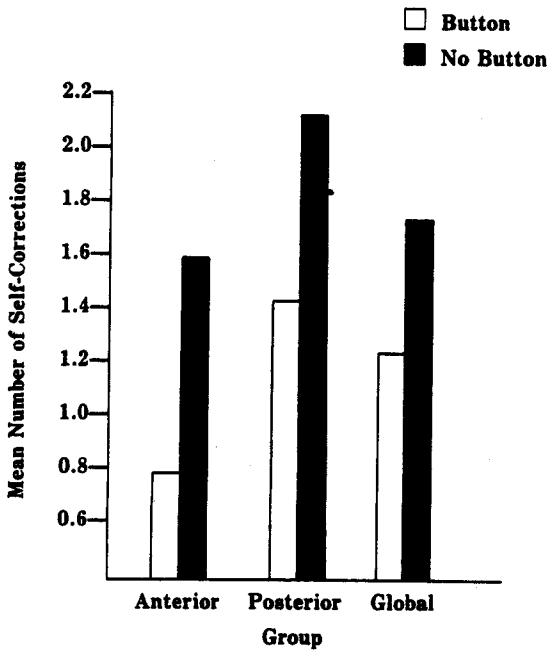


Figure 13. Mean number of self-corrections in Button and No Button conditions for Anterior, Posterior, and Global groups.

Raven, J. Coloured Progressive Matrices: Set A, AB, B. London: H.K. Lewis Co. Ltd., 1956.

Wertz, R.T. and Lemme, M.L. Input and output measures with aphasic adults. Research and Training Center 10, Final Report, Social Rehabilitation Services, Washington, D.C., 1974.

DISCUSSION

Q: Was the presentation of the test versions counterbalanced?

A: Yes

Q: These are means, but I wonder if there were patients that had a learning effect or not.

A: We could not detect a trend or any indication that there was a learning effect. It was not striking. I can go back and look at the individual data and get back to you on that.

Q: What arrangements did you make with the publishers of Progressive Matrices about using their test on the computer?

A: We had understood that since it is in the public domain that this is not a concern; in addition, it is not up for distribution at this time.

Comment: It's a very interesting question about putting tests into the computer. The laws are quite stringent. When you do that it's always good to make sure you have something in writing saying that you can use the tests in computerized versions. The arrangements for copyright and licensing are fairly complex.