SESSION V

ADAPTIVE TESTING

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A new strategy for studying spatial aptitude

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A new approach to testing for and training in spatial aptitude is described. Figural analogy problem terms from the cognitive abilities test are photodigitized and arrayed in zones on the computer screen; they can be seen only when selected with the mouse (i.e., one at a time). Viewing patterns and durations can then be analyzed to assess problem encoding and solution strategies. Implications are discussed.

Spatial aptitude, as measured by performance on specific standardized tests, is highly predictive of academic success in science and mathematics, and it is widely used as a "knowledge-free" index of general intelligence. Yet experimental work on the cognitive characteristics underlying spatial aptitude—and on the degree to which these characteristics can be developed through training—has only just begun. The approach we have taken is to apply the expert/novice paradigm to the study of spatial aptitude, demonstrating qualitative differences in encoding and solution strategies between high and low "spatials," which are similar to expert-novice differences in various problem domains. Our first efforts have focused on the ubiquitous figural analogy test (A:B::C:D). Converging evidence from a variety of standard tasks indicates that high scorers encode figures more flexibly, apply spatial transformations more holistically, and attempt to solve problems in a more top-down manner than do lows (see Schiano, Cooper, Glaser, & Zhang, 1989); but pilot results also suggest that at least some of these skills may be trainable. A new methodology has been developed to computerize testing and training in future research.

Experimental Procedure and Program Description

Figural analogy test problems from the cognitive abilities test were photodigitized and stored on disk on an Amiga 2000 computer as bit-mapped memory images. A program called ANALOGY was written in AmigaBASIC

to administer the test and to record data from all trials. The procedure is as follows: The subject first views an instruction screen and is prompted to enter his or her name. Next, a blank cover screen shows only a centered cross-hair while a picture file is read in and broken up by ANALOGY into zones corresponding to the analogy terms (A:B::C:D1,D2,D3,D4,D5). The subject clicks a mouse key to initiate the trial. The three analogy stem terms (A:B::C: . . .) are arrayed on the screen above the five answer alternatives (D1 . . . D5). None of the terms is immediately visible, however; the zone corresponding to each term shows only a black box. The subject moves the cursor (by moving the mouse) to the appropriate zone and clicks to select a term to view. (Microcode libraries and blitter [block-transfer] hardware in the Amiga allow the use of dynamic color-mapping, so that only one term is visible at a time while the other zones are mapped to background color [i.e., black]. This feature allows even a program written in BASIC to flash images on the screen without scrolling or perceptible write time.) The trial ends when the subject indicates a choice of an answer by clicking twice on one of the answer terms. A record of viewing order and reaction times for each trial is saved in a log file, which can be analyzed in a number of ways.

This experimental procedure has much in common with the subject-controlled moving window technique now commonly seen in the text-comprehension literature. However, it allows the subject complete freedom in selecting what to view and when to view it. In this sense, the method is more similar to recording eye-movement patterns during problem solution. Yet it is far easier to administer and the data is much cleaner than eye-movement results. In any case, the computerized procedure consti-

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tutes a clear advance over paper-and-pencil tests, and even over standard reaction time studies, since it yields a rich database gathered under unobtrusive yet controlled conditions. In addition to overall speed and accuracy of solution, the database provides for direct assessments of specific problem term encoding and comparison times (and viewing patterns), and of global solution strategies (e.g., top-down vs. bottom-up).

Since this general procedure is expected to become the basis of a large research effort, the program was designed to be general purpose and easy to modify. Stimulus presentation order, screen format, and the number of terms visible at a given time can be varied to permit the use of different test conditions or types of stimuli.

One variant of the program implements training through testing with immediate feedback. As soon as the subject's answer selection is made, speed and error feedback information is provided. If the answer chosen is incorrect, the program redisplayes the same problem until it is correctly solved, randomizing the spatial layout of the answer alternatives (if desired). We expect to use this training procedure to study the effects of specific instruction and practice conditions on performance. One of the advantages of this approach is that it will allow fine-grained analyses of changes in encoding and solution strategies, as well as improvements in speed and accuracy (overall and for specific problem types). The eventual goal is to be able to tailor training to focus on individual areas of weakness as needed.

In short, a powerful research tool of general applicability and long-term utility has been developed. It will be used to run an entire program of research, varying subject populations and specific training conditions, and examining transfer to other tests and tasks. Initial training data has already been gathered, and analyses are cur-

rently in progress. To the extent that the analogy between spatial aptitude and expertise does hold, some improvement with training should be found. Our aim is to develop a tool with which standardized testing may be used not merely to exclude, but also to educate.

Program Requirements

ANALOGY is currently designed to run on an Amiga 1000 or 2000 computer. As mentioned above, the Amiga is especially well designed for the manipulation of screen graphics. Versatile software library functions designed to use the graphics hardware are easily available from AmigaBASIC, so that many windows on up to four logical screens can be shuffled like sheets of paper, with only the top screen visible. In addition, a simple function call from an AmigaBASIC program can black out or restore any portion of any window. However, since BASIC cannot handle picture compression in a timely manner, each problem must be stored as a separate bit-mapped memory image requiring 48K of disk space. In future versions, we hope to either translate the program into a higher language (e.g., C) or to develop a method of manipulating file formats so that a compression algorithm can be used to lower disk space requirements.

Program Availability

A listing of the program is available at no charge from: Diane J. Schiano, Psychology Department, 436 Jordan Hall, Stanford University, Stanford, CA 94305.

REFERENCE

- SCHIANO, D. J., COOPER, L. A., GLASER, R., & ZHANG, H. C. (1989). Highs are to lows as experts are to novices: Individual differences in the representation and solution of standardized figural analogies. *Human Performance*, 2, 225-248.