PC-compatible computer-generated stimuli for video-task testing

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Whereas computer technology allows for the automation of experimentation and data collection, the process of stimulus production has remained a relatively labor-intensive process. A program for automatic computer generation of novel nonverbal stimuli is described in this paper. The program, STIMGEN, allows menu-driven control over the type and appearance of stimuli. Data are presented in which two monkeys matched to sample with high accuracy using stimuli generated with STIMGEN. These data are interpreted to support the usefulness and value of automatic stimulus generation in a variety of applications.

One of the most successful applications of computer technology in experimental psychology has been the use of computers to manage stimulus production and display. Computer programs for automated management of words and slides as stimuli in psychological research have been presented (Greene, Ratcliff, & McKoon, 1988; Stoddard & Loftus, 1988). The production and presentation of computer-graphics stimuli—forms, pictures, and patterns—which allow a medium of presentation for nonverbal stimuli comparable to the popular practice of displaying lists of words on a computer screen is described in the present paper.

Computer-generated stimuli have been employed with great success with human subjects (including adults, normally developing children, and mentally retarded individuals) and with a variety of nonhuman primate subject populations. Data obtained from these diverse populations have been applied to basic questions of cognitive, neuropsychological, social, developmental, and comparative psychology (see, e.g., Hopkins & Morris, 1989; Rumbaugh, Richardson, Washburn, Savage-Rumbaugh, & Hopkins, 1989; Washburn, Hopkins, & Rumbaugh, 1989a, 1989b). In this paradigm, any computer-generated image can be used as a stimulus in psychological experimentation. Words, pictures, random forms, colors, and so forth can be used and combined to form a nearly endless array of potential stimuli for investigation of constructs such as learning, memory, perception, imagery, laterality, and language.

As is the case with research involving traditional apparatus, however, there are two potential drawbacks to this method of stimulus generation. Each of the stimuli must be manually selected or constructed before it can be used. In addition, each stimulus must be stored and catalogued for use. For example, Washburn et al. (1989a, 1989b) have reported a series of experiments on learning and memory in macaques (*Macaca mulatta*), in which all stimuli were selected or constructed from a popular graphics program. Over 500 different computer-generated stimuli were developed with this graphics package. This represents an investment of time, albeit the time required was substantially less than that which is required for traditional stimulus-generation methods (e.g., slides, junk objects, etc.). Also, almost 1MB of storage space was necessary to maintain all of the stimuli on disk for this experiment alone!

In the present report, a PC-compatible program (STIMGEN) for automatic production of computer-generated stimuli is described.¹ With it, stimuli can be generated and saved in libraries that can be utilized by any compatible video task. Note that, although these stimuli were developed for use with the video-formatted tasks developed at our laboratory, they can be used directly by any similar program or task (i.e., any program employing the Basic GET, PUT, and BLOAD commands). Thus, by utilizing the STIMGEN program, one can access a large pool of stimuli without intensive time, effort, or storage demands.

Program Characteristics

The STIMGEN program currently utilizes six algorithms for generating a library of eight different stimuli each time the program is executed. Development of additional algorithms can be integrated into the present program. Each algorithm can be enabled or disabled from a menu. Consequently, a library of stimuli of a particular type (algorithm) or set of types can be constructed, or, alternatively, a library of stimuli of randomly selected types can be generated.

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LEXIGRAM stimuli (LEX) are forms constructed of combinations of simple elements (Rumbaugh, 1977). CHECKERBOARD (CHECK) stimuli are formed by filling a random number of grids within a 3×4 matrix. ASCII stimuli are built by printing strings of randomly selected characters from the computer character set. LINES stimuli are made by drawing a random number of lines from randomly selected starting and ending points. BALLS are stimuli composed of a random number of randomly sized filled circles. FORMS are like LINES stimuli, except that each stimulus is constrained to produce a closed random figure. A MIXED stimulus library is formed by combining these six generation algorithms. Examples of each type of stimulus appear in Figure 1.

The size of each stimulus is 70×80 pixels. Of course, the physical size of each will depend on the dimensions of the monitor used. Each stimulus measures approximately 4.5×5.5 cm on a 13-in. monitor. The stimuli may be either monochromatic or colored, again menu-selectable. The number of colors available (3 or 16) is set according to the system video driver/monitor capabilities.

Each library of stimuli is saved into a bit-mapped file (BSAVE), occupying 16,391 bytes of storage. A description of each stimulus is saved in a data file; these descriptive data can then be utilized in later analysis.

Of course, a critical issue with regard to stimuli such as these is discriminability. Consequently, the following investigation was undertaken to determine whether performance levels in which stimuli from libraries generated by STIMGEN would be comparable to levels previously

reported (Washburn et al., 1989b) when manually selected or drawn figures, pictures, and shapes were used as stimuli.

Method

Subjects. Two male rhesus monkeys (*Macaca mulatta*; Abel and Baker) were subjects in this investigation. The animals, each 7 years old, had participated previously in a variety of investigations and were skilled at manipulating a joystick to respond to computer-generated stimuli in the video-task paradigm (for discussion of their training and testing history, see Rumbaugh et al., 1989; Washburn et al., 1989b). Neither animal was restrained, food deprived, or fluid deprived in this study.

Apparatus. The animals were tested using the Language Research Center Computerized Test System (see Rumbaugh et al., 1989). It consists of a Zenith Z-159 computer and color monitor for presenting stimuli, receiving responses, and maintaining data. A standard analog joystick is used as the response manipulandum, and movement of the joystick controls movement of a computer-generated cursor on the screen. Sound is generated by the computer through an external speaker/amplifier and is used to provide positive and negative feedback. In addition, appropriately performed trials are signaled by the automatic delivery of a 97-mg fruit-flavored chow pellet (Noyes).

This apparatus, protected by clear acrylic panels, is currently mounted on a cart that can be secured directly in front of each animal's home cage. The animal is thus able

Figure 1. Examples of each of the types of stimuli produced by STIMGEN and used in this study.

Figure 2. Percentage correct for matching-to-sample as a function of stimulus type.

to reach through the mesh of the cage and manipulate the joystick without compromising visual access to the events on the screen.

Procedure. The animals were tested in blocks of 40 matching-to-sample trials. On each trial, one of the eight stimuli would be randomly selected as the sample and a second stimulus selected as the foil. The sample stimulus was then presented on the screen in a random location, separated from the cursor (located midscreen) by at least 5 cm. Through manipulation of the joystick, the cursor could be brought into contact with the sample, at which time the sample disappeared. The sample was removed from the screen to maximize the demands upon encoding and to attenuate the likelihood of ceiling effects. Immediately after the sample disappeared, the two choice stimuli were displayed on the screen. These two stimuli, the foil and the sample, were presented in random loci with the constraint that at least 5 cm separate each from the other and from the cursor. Moving the cursor to the matching stimulus (the sample) resulted in a rising tone (400–1000 Hz) and a reinforcer. Responses to the nonmatching (foil) stimulus resulted in a 50-Hz buzz for 2 sec and no reinforcer. In either case, the trial ended followed by a 5-sec intertrial interval and the next trial.

The same library of eight stimuli was used within each block of 40 trials, such that each stimulus was used as the sample on 5 trials on the average. The library of stimuli was changed between blocks of trials. The type of stimulus employed (i.e., the stimulus-generation algorithm) was assigned in a randomized block design. For example, the first block of trials might utilize lexigram stimuli; the second block might employ the checkerboard; and so forth, until all stimulus types, including the mixed library option, were used.

A total of 400 trials (10 blocks of 40 trials) was assigned for each stimulus type: 200 trials with monochromatic stimuli and 200 trials in which colored stimuli were employed (only 200 trials with ASCII stimuli were obtained because colored ASCII stimuli cannot currently be produced by STIMGEN).

Results

Mean percentage of trials in which correct responses were made, as a function of stimulus type, is displayed in Figure 2. Also available in Figure 2 is a baseline level of matching-to-sample performance (BASE), based on the data reported previously for the 2 animals of the present study (Washburn et al., 1989b). The procedure was identical in this baseline study to that of the present experiment, except that manually produced drawings of forms and shapes (e.g., a tree, a crown, a star) were used as stimuli in the former.

Discussion

Performance was generally high, despite the overall increase in similarity of the stimuli generated by STIMGEN relative to the hand-drawn stimuli used in the baseline study. This is particularly true for colored mixed stimuli, in which the interstimulus similarity was minimized. On the other hand, stimuli within a stimulus type such as LINES stimuli were more difficult to match, suggesting a value for experiments in which near-perfect performance is less desirable (e.g., visual acuity studies, divided visual field techniques).

On the whole, these data support the viability of stimuli randomly generated by the STIMGEN program for experiments in which processing of nonverbal stimuli is examined. It may be suggested that such stimuli would be

ideal for automated investigations of learning, memory, and perception in a variety of subject populations.

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NOTE

- 1 Although the STIMGEN program is too lengthy to reproduce, it is available for \$10 (U.S.) from the Language Research Center. Also included is documentation that provides programming details for integrating STIMGEN into any existing research.