Consistent attending versus consistent responding in visual search: Task versus component consistency in automatic processing development

ARTHUR D. FISK

AT&T Communications and University of Cincinnati, Cincinnati, Ohio

and

WALTER SCHNEIDER

University of Illinois, Champaign, Illinois

The current research examined whether the total processing, from stimulus to response, must be consistent for automatic processing to improve task performance. Consistent versus inconsistent attending and responding (i.e., response translation) were factorially combined. Results showed that the consistency of attending produced substantial practice effects. However, consistency of the motor response translation component did not affect the asymptotic performance level. The results indicate that automatic processing develops for consistent components of a task even when the entire task is not consistent.

The consistency with which subjects are able to deal with stimuli has important implications for performance in memory, detection, and search experiments. For example, in a visual search paradigm, Schneider and Shiffrin (1977, Experiment 2) found that reaction times in conditions in which subjects could consistently attend and respond to stimuli were 580 msec; when attending was not consistent, reaction times were 1,290 msec. Previous research has shown that, in general, when subjects consistently attend *and* respond to stimuli, their performance becomes less dependent on processing load, requires less effort, is more accurate, and is faster (e.g., Corballis, 1975; Egeth, Atkinson, Gilmore, & Marcus, 1973; Kristofferson, 1972; Logan, 1978, 1979; Neisser, 1974; Rabbitt, 1978; Schneider & Fisk, 1982a, 1982b; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; for a review, see Schneider, Dumais, & Shiffrin, 1984).

The substantial changes in performance that occur with extended practice have led researchers to propose two qualitatively different forms of human information processing (Hasher & Zacks, 1979; James, 1890; LaBerge, 1973, 1975; Logan, 1978, 1979; Norman, 1976; Posner & Snyder, 1975; Shiffrin & Schneider, 1977). In this

paper, these two processes are referred to as automatic and controlled processing (see Shiffrin & Schneider, 1977). Automatic processing occurs when stimuli are *consistently mapped* (CM), such that whenever a particular stimulus occurs, the subject always attends and responds to it in the same way. Controlled processing is used either when the task is novel or when there is a *varied mapping* (VM) condition, subjects vary the attending and responding to specific stimuli (e.g., on one trial, the subjects respond to each digit that appears, and on the next trial, they respond to letters but ignore digits).

Consistent attending is a necessary condition for practice to improve search performance (Logan, 1979; Schneider & Fisk, 1982a, 1982b). Schneider and Fisk (1982a) showed that the lower the consistency of attending, the less subjects will benefit from search practice. In fact, when subjects ignored a specific letter twice as often as they attended to it, 840 trials of searching for a given letter (6,720 total trials) produced no improvement in performance.

In this experiment, we addressed whether or not the concept of consistency in training must relate to the entire task. Can total task performance benefit by automatic process development on consistent task components? If automatic processing were limited only to those tasks that are consistent from stimulus to response, then it would have little relevance in the natural environment, in which few tasks are completely consistent. However, if inconsistent task components do not substantially reduce improvement of the consistent task

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components, then automatic processing concepts should have a wide range of applicability.

The effects of consistency of attending and consistency of motor response on the development of automatic processing were examined by factorially combining these variables. Subjects participated in a multiple-frame-detection paradigm. They detected single targets in a rapidly displayed series of characters presented visually across four channels. Attending was either consistent or inconsistent.

METHOD

Trial Sequence

Each trial consisted of the following sequence: (1) A 2-sec response orientation display indicated the *upcoming* response condition by displaying either the word "same" or the word "different." (2) Next, the memory set and accuracy feedback were displayed. The percentage of accuracy for the block was presented 1 deg to the right of the memory set display. The subjects were given up to 30 sec to study the target item; when ready, they terminated the memory set display by a button push. (3) Following the memory set display and preceding the frame sequence was a 500-msec presentation of the fixation dot. (4) The frame sequence consisted of 12 frames presented in rapid succession. Each frame was composed of four letters in a square around a center fixation dot. The frames were presented for 80 msec followed immediately by four random dot masks (presented for 30 msec).

The target frame, target display location, and distractor characters were determined randomly with the following restrictions: (1) No characters appeared in the same display position on two successive frames, and (2) the target could not occur on the first two frames or the last frame of the sequence.

The subjects' task was to indicate the target's location by pushing one of four buttons arranged in a square. For the *consistent-responding* conditions, the response translation rule always required the subjects to push the response button corresponding to the target's actual display position (a one-to-one mapping). For the *inconsistent-responding* conditions, there were two response translation rules. The subjects responded either with the one-to-one mapping rule or with a row reversal of the target's actual display position (e.g., if the target was in the lower left quadrant, the subjects pushed the upper left button). Any response less than 150 msec or greater than 3 sec (from the target frame presentation) was considered invalid and was deleted from the reaction time analysis. A target was presented on each trial. The subjects were instructed to guess a location if necessary. On error trials, the subjects heard a short tone. On correct trials, a random dot pattern would spin across the screen from the target's location. Also, the subjects received a "skill rating" that corresponded to a given accuracy level.

Design

The independent variables manipulated were: (1) consistency of attending—the relationship between a given target letter and the distractor set was either consistent or varied in its mapping; and (2) the consistency of the motor response—the relationship between the target letter and the response translation was either consistent or varied. During training blocks, these two variables were factorially combined and varied between trials. One letter was assigned to the consistent-attending/consistent-responding (CM/CM) condition, and one letter to the consistent-attending/inconsistent-responding (CM/VM) condition. Four letters were assigned to the inconsistent-attending/consistent-responding (VM/CM) condition, and three letters to the inconsistent-attending/inconsistent-responding (VM/VM) condition. The design was within subjects. Order of letter assignment was con-

trolled by a partial Latin square. From the subjects' perspective, the task was to search for letters, with some trials being "same" response conditions and some trials being "different" response conditions.

First, the subjects completed 12 blocks of training under the attending/responding conditions described above. Each block of trials contained 12 trials per condition (randomly intermixed), for a total of 48 trials. After each set of 12 training blocks (576 trials), 1 block of 80 trials was presented as a test of detection accuracy under consistent-responding conditions (i.e., all trials were "same" trials). All subjects completed four of these training/test cycles in six 50-min sessions.

Stimuli

Nine upper case letters (A, C, D, E, M, R, S, U, and Z) were used. The letters were counterbalanced across conditions. The letters were constructed from dots on a rectangular grid 32 dots wide x 48 dots high, and characters subtended .58 deg in height and .52 deg in width. The refresh rate of the dots making up the stimuli was 10 msec. The room was dimly lit [.4 fc (4.3 lx) incidental light], with the dots easily visible on the display [.005 fL (.017 cd/m²) per dot, P31 phosphor]. The subjects sat 45 cm from the display. With fixation at the center dot, the characters subtended 1 deg of visual angle.

Equipment

The experiment was computer controlled; error tones and white noise (80 dB) were presented through a headset.

Subjects

Nine subjects from the University of Illinois were paid for their participation. All subjects had normal or corrected-to-normal vision, were right-handed, and reported that English was their native language.

RESULTS

The position accuracy data, corrected for guessing [$P(\text{corrected}) = P(\text{correct}) - 1/3 P(\text{error})$], are presented in Figure 1. Figure 1a presents the training data, with each point (per condition) representing the averaged accuracy across the 12 blocks of training prior to a test block. Figure 1b shows the test data.

Considering the training data, analysis of the simple main effects of practice (groups of 12 trial blocks) showed significant practice effects for the CM/CM condition [$F(3,24) = 10.14, p < .05$], the CM/VM condition [$F(3,24) = 6.34, p < .05$], and the VM/VM condition [$F(3,24) = 10.20, p < .05$]. Practice did not have a significant effect in the VM/CM condition [$F(3,24) = 2.23, p > .05$]. The comparisons between conditions revealed that the inconsistent-attending conditions differed from each other [$F(1,8) = 9.12, p < .05$]. The consistent-attending conditions did not differ from one another ($F < 1$).

The test-block data (Figure 1b) showed that the inconsistent response component did not influence detection accuracy ($F < 1$) within a given attending condition when the subjects were transferred to completely consistent responding, but the consistent-attending conditions were superior to the inconsistent-attending conditions ($p < .05$ for all cases).

The test-block reaction time main effects of attending and training motor responding were significant

Figure 1. (a) represents training data. Numbers on the abscissa represent groups of training blocks (12) prior to each intervening test. (b) presents the intervening test data. Numbers on the abscissa represent intervening test. Training and test blocks are presented separately only for clarity. CM/CM—consistent attending and responding; CM/VM—consistent attending/inconsistent responding; VM/CM—inconsistent attending/consistent responding; VM/VM—inconsistent attending and responding.

[$F(1,8) = 33.56$, $p < .05$, and $F(1,8) = 6.18$, $p < .05$], respectively (CM/CM = 1,338 msec; CM/VM = 1,372 msec; VM/CM = 1,431 msec; and VM/VM = 1,485 msec). A separate analysis of variance of the last test (Test 4) revealed a significant effect of attending [$F(1,8) = 7.395$, $p < .05$]. During the last test block, reaction times to the letters trained under inconsistent-responding conditions were 64 msec slower than the consistent-responding reaction times, although this difference was not statistically significant [$F(1,8) = 4.31$, $p = .071$]. The averaged reaction times (in milliseconds) for the last test block were: CM/CM=1,351; CM/VM=1,438; VM/CM=1,473; and VM/VM=1,519.

DISCUSSION

The data show that consistent attending produces an improvement in search performance and that an inconsistent-responding component neither inhibits nor substantially slows the improvement rate. The inconsistent-response translation did reduce detection performance in the training blocks. Inconsistent responding could reduce performance in two ways. First, subjects could forget if they were in a "same" or a "different" response trial and then correctly detect the target but respond with the inappropriate position. Second, the additional load induced by maintaining the S-R mapping in short-term memory could reduce resources available for the detection process (e.g., Logan, 1979, 1980).

Our research suggests that the criterion of consistency, although clearly the important variable for automatic processing development, need not relate to the entire task. Automatic process development can improve total task performance by

improving performance on consistent task components even if the total task is not consistent.

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