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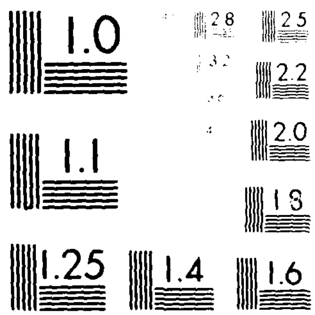
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TASK VERSUS COMPONENT CONSISTENCY IN THE DEVELOPMENT OF AUTOMATIC PROCESSES: CONSISTENT ATTENDING VERSUS CONSISTENT RESPONDING

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REPORT HARL-ONR-8106

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Previous visual search experiments have shown that training to consistently respond to a stimulus results in substantial improvements in performance. The current research examines whether the total processing, from stimulus to response, must be consistent for this improvement to occur. The experiment factorially combined consistent versus inconsistent attending and responding. In a multiple frame target detection paradigm, subjects detected single character targets in rapidly presented frames of four characters. Results showed inconsistent motor responding slowed detection improvement and

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reaction time. However, after extended training training, no differences in detection accuracy existed between consistent and inconsistent motor responding if attending was consistent. The present research indicates that the notion of consistency need not relate to the entire task. Even if some stages of processing are inconsistent, consistency within a stage can lead to development of automatic processing. Implications for the development of automatic component processes are discussed.

Task Versus Component Consistency in the Development of Automatic Processes:

Consistent Attending Versus Consistent Responding

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Abstract

Previous visual search experiments have shown that training to consistently respond to a stimulus results in substantial improvements in performance. The current research examines whether the total processing, from stimulus to response, must be consistent for this improvement to occur. The experiment factorially combined consistent versus inconsistent attending and responding. In a multiple frame target detection paradigm, subjects detected single character targets in rapidly presented frames of four characters. Results showed inconsistent motor responding slowed detection improvement and reaction time. However, after extended training, no differences in detection accuracy existed between consistent and inconsistent motor responding if attending was consistent. The present research indicates that the notion of consistency need not relate to the entire task. Even if some stages of processing are inconsistent, consistency within a stage can lead to development of automatic processing. Implications for the development of automatic component processes are discussed.

A

Consistent Attending Versus Consistent Search: Task Versus Component Consistency in Automatic Processing Development

When subjects consistently attend and respond to specific stimuli their performance improves substantially with practice. For example, in a visual search paradigm, Schneider and Shiffrin (1977, Experiment 2) found that reaction times in conditions where subjects could consistently attend and respond to stimuli were 580 msec; when attending was not consistent reaction time was 1290 msec. Similarly, Moray (1975) found target detection performance improved 22 percent, from 73 percent to 94 percent correct detections, over five hours of monitoring two auditory channels. Previous research has shown that, in general, when subjects consistently attend <u>and</u> respond to stimuli, their performance becomes less dependent on processing load, requires less effort, is more accurate and is faster (see for example, Corballis, 1975; Egeth, Atkinson, Gilmore, & Marcus, 1973; Kristofferson, 1972; Logan, 1978, 1979; Neisser, 1974; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Schneider & Fisk, in press - a; for a review, see Schneider, Dumais, & Shiffrin, in press).

The substantial changes in performance that occur with extended practice have led researchers to propose that there are two qualitatively different forms of human information processing (James, 1890; Hasher & Zacks, 1979; LaBerge, 1973, 1975; Logan, 1978, 1979; Norman, 1976; Posner & Snyder, 1975; Shiffrin & Schneider, 1977). In the present paper these two processes will be referred to as automatic and controlled processing (see Shiffrin & Schneider, 1977). <u>Automatic processing</u> is a fast, parallel, fairly effortless process that is not limited by short-term memory capacity, is not under direct subject control, and allows performance of well-developed skilled behaviors. Automatic processing occurs when stimuli are <u>consistently mapped</u> (CM) such that whenever a particular stimulus occurs the subject always attends and responds to it in the same way. The second process, <u>controlled processing</u>, is a slow, generally serial, effortful, capacity limited process. Controlled processing is under direct subject control and is used to deal with novel or inconsistent information. Controlled processing occurs either when the task is novel or there is a varied mapping between responses across trials. In a <u>varied mapping</u> (VM) condition subjects vary the attending and responding to specific stimuli (e.g., on one trial the subject responds to each digit which appears, and on the next trial responds to letters but ignores digits).

Consistent attending appears to be a necessary condition for practice to improve search performance (Logan, 1979; Schneider & Fisk, in press - b). Schneider and Fisk (in press - b) have shown 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 training produced no improvement in performace.

An unresolved issue regarding automatic process development concerns the importance of consistent responding. Does inconsistent responding slow or inhibit performance improvement? If automatic processing were limited only to tasks which allow consistent processing from stimulus to response, it would have little relevance in the natural environment. For example, one does not always respond in the same manner when a traffic light turns red. If inconsistent motor responding inhibits or even substantially slows automatic processing development, the number of automatic processes a human could employ would be quite limited.

However, if inconsistent responding does not substantially reduce performance improvement of the consistent task components, then automatic processing concepts should have a wide range of applicability. In this case, consistent components of tasks would become automatic (i.e., faster, more accurate, less effortful, under less subject control), even when the total processing task is not consistent from stimulus to response. Therefore, as an example, extensive practice at consistently attending to traffic lights might cause you to always attend to a change in the light even when your response varies in relationship to the situation.

The effects of consistency of the attending and motor response on the development of automatic processing were examined in the present experiment by factorially combining these variables. Subjects participated in a multiple frame detection paradigm where they detected single targets in rapidly displayed characters presented visually across four channels. The subjects either attended consistently or inconsistently to a given letter; that is, the letter either appeared only as a target (consistent attending) or functioned as a target on some trials and as a distractor on other trials (inconsistent attending). In addition, the responding to a given letter was either consistent or inconsistent. That is, upon target detection, the subject either always responded the same way to a given letter (consistent responding) or responded in different ways to a given letter on different trials (inconsistent responding).

Method

Trial Sequence. Figure 1 shows a representative trial sequence. The stimuli were presented on a cathode ray scope. Each trial consisted of the following sequence: 1) An orientation display, which contained an indication of the upcoming response condition by displaying either the word "same" or "different", was presented for two seconds. 2) The memory set was presented next in the upper left hand corner of the screen. In addition, accuracy feedback was presented in this display. This feedback was a two digit number presented to the right of the memory set display and was separated from the target item by approximately 1 degree visual angle. The feedback was the average accuracy during a given block of trials and was initialized to zero prior to each trial block. The subjects were given up to 30 seconds to study the target item and initiate the trial sequence. The subjects initiated the remaining part of the trial sequence by a button push with the index finger of their left hand. This button push terminated the memory set display. 3) Following the memory set display and preceding the frame sequence was the presentation of the fixation dot for 500 msec. This provided a fixation point corresponding to the central fixation dot of the frame sequence. 4) The frame sequence consisted of 12 frames presented in rapid succession. Each frame was composed of four letters presented for 80 msec followed immediately by four random dot masks. The masks were presented in the same display positions as the letters for 30 msec. These elements were positioned to form a square around a center fixation dot. The display time of the letters plus the display time of the masks yielded a total frame time of 110 msec.

Insert Figure 1 about here

The distractor characters were randomly distributed on each frame with the restriction that no character appeared in the same display position on two successive frames. The target item was presented on a randomly determined frame. However, the target could not occur during the first two or last frame of the frame sequence. The display location of the target within the target frame was randomly determined.

The subjects' task was to indicate the target's location by pushing one of four buttons with their right index finger. These buttons also formed a square. For the consistent responding conditions, subjects always pushed the response button corresponding to the target character's actual display position (a one-to-one mapping). For the inconsistent responding conditions, subjects responded either with a one-to-one mapping or with a row reversal of the target's actual display position (e.g., if the target was in the lower left the subject pushed the upper left button). Any response less than 150 mec or greater than 3 seconds (from the target frame presentation) was considered invalid and deleted from the reaction time analysis. Since a target was presented on each trial, the subjects were instructed to guess the correct response at the end of the frame sequence if they did not detect the target.

At the end of each trial the subject received an error tone if an incorrect response was made. Also, the subject received a skill rating which corresponded to a given accuracy level. The skill rating was indicated by flashing one of four colored lights on the subject's response box. If a correct detection was made, a random dot pattern would appear to spin off the screen from the target's display location.

Design. The independent variables manipulated were: 1) consistency of attending -- the relationship between the memory set and the distractor set being either consistent or varied in its mapping; and 2) the consistency of the motor response (i.e., how subjects responded upon target detection) also being either consistent or varied. These two variables were factorially combined and varied between trials. For each subject, one letter was assigned to each consistent attending conditon; that is, one letter was assigned to the consistent attending/consistent responding (CM/CM) condition and one 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 controlled by a partial Latin square.

The experiment was divided into training and testing blocks. First, the subjects completed 12 blocks of training under the above mentioned attending/responding conditions. Each block of trials contained 12 trials per condition for a total of 48 trials. After each set of 12 training blocks, one block of 80 trials was presented as a test of detection accuracy under consistent responding conditions. For the test block, responding was consistent across all of the attending conditions. All subjects completed four of these training/test cycles. Each subject participated in six sessions of 50 minutes.

Stimuli. The characters used in the experiment were nine upper case letters of the English alphabet. The characters were constructed from dots on a rectangular grid 32 dots wide by 48 dots high with the characters subtending .58 degrees in height and .52 degrees in width. The refresh rate of the dots making up the stimuli was 10 msec. The room was dimly lit (.4 foot candles incidental light) with the dots easily visible on the display (.005 foot lamberts per dot). The display of the characters was divided into frames where each frame consisted of four characters positioned to form a square around a center fixation dot. The subjects sat 45 cm from the display. With fixation at the center dot, the visual angle subtended by the characters was one degree.

The letters used were: A, C, D, E, M, R, S, U, and Z. The choice of the above letters was based upon the results of a series of experiments indicating that these letters were the most equally confusable as a group given the font and multiple frame presentation of the present experiment. To minimize any remaining letter effects, letters were counterbalanced across conditions.

Equipment. The experiment was controlled by a Digital Equipment Corporation PDP 11/34 computer. The computer was programmed to present the appropriate stimuli, collect responses, and control timing of the display presentation. The stimuli were presented on Tektronics Model 604 and 620 cathode ray scopes which contained P-31 phosphors. Each subject wore a headset through which white noise (80db) and the error tone were carried.

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

Results

Position accuracy data, corrected for guessing (P(corrected) = P(correct) - 1/3 P(error)), are presented in Figure 2. Figure 2a 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 2b shows the test data.

Insert Figure 2 about here

Considering the training data, analysis of the simple main effects of practice (groups of 12 trial blocks) showed that the effect of practice was significant 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 2b) show that the inconsistent response component did not influence detection accuracy within a given attending condition when the subjects were transferred to completely consistent responding. The comparisons between conditions show that the CM/CM and CM/VM conditions did not differ from one another ($F<1$). The VM/CM and VM/VM conditions did not differ ($F<1$). The comparisons between the consistent attending and inconsistent attending conditions showed that regardless of the response condition the consistent attending was superior ($p<.05$ for all cases).

Correct trial reaction times collected during test blocks are plotted in Figure 3. Collapsing across tests, the main effects of attending and motor responding (i.e., type of responding during training) were significant [$\underline{F}(1,8)=33.56$, $\underline{p}<.05$ and $\underline{F}(1,8)=6.18$, $\underline{p}<.05$], respectively. A separate analysis of variance of the last test (test 4) was also conducted. This analysis revealed a significant effect of attending [$\underline{F}(1,8)=7.395$, $\underline{p}<.05$]. During the last test block, the inconsistent motor responding training condition responses were 64 msec slower than the consistent responding reaction times although this difference was not statistically significant [$\underline{F}(1,8)=4.31$, $\underline{p}=.071$].

Insert Figure 3 about here

Discussion

The data show that consistent attending produces an improvement in search performance and that inconsistent responding neither inhibits nor substantially slows the improvement rate. Both of the consistent attending conditions were superior to the inconsistent responding conditions. Only the consistent attending test block conditions improved with practice. The inconsistent responding during training did not affect position accuracy during test blocks.

The inconsistent responding conditions did reduce detection performance in the training blocks. The additional load of maintaining response information in the inconsistent responding conditions could reduce performance in two ways. First, subjects could forget if they were in a "same" or "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. Logan (1979) has shown that increasing the number of irrelevant characters in short-term memory can slow search reaction times in inconsistent attending conditions (also see Logan, 1980).

The effect of inconsistent responding did result in a greater reduction in performance during training in inconsistent attending conditions (22%) than in the consistent attending conditions (9%). This result is in line with previous research showing that automatic processing is less resource sensitive than control processing (Logan, 1979; Schneider & Fisk, in press - a, in press - b). Logan (1979) has shown that after extensive practice in consistently attending to a stimulus, search performance is insensitive to increases in short-term memory load. However, with inconsistent attending (varied mapping) the search process remains sensitive to short-term memory load. Given sufficient practice we feel that performance in the CM/VM condition would match the CM/CM condition during the training blocks (in the present experiment they are not significantly different). However, since the increased resource cost due to maintaining both the memory set <u>and</u> the appropriate S-R mapping should not be eliminated with practice in the VM/VM condition, we would expect the significant difference between the VM/CM and VM/VM conditions (observed during the training blocks) to remain even after extended training.

The results clearly show that automatic processing can develop for a component process even while the total task is not consistent. The presence of an inconsistent motor response reduced training performance but did not affect test block detecton rate or improvement rate. This suggests that the performance improvement associated with automatic processing -- that is, faster, more accurate and less effortful processing -- should occur when component processes are consistent. In the present experiment, each time a target occurrred the subject consistently attended to it. Therefore, the component process of attending to the stimulus should become automatic. We expect many complex processes to include automatic component processes even if the total task is not consistent. Furthermore, we interpret the development of a skill as the production of automatic component processes, which process all the consistent elements of the task, such that limited control processing resources can be utilized to deal with the non-consistent elements of the task (see Schneider, Dumais, & Shiffrin, in press).

Returning to our traffic light example, the detection of the change to a red light and the allocation of attention for dealing with the change would be automatic. However, the response to the light would be a controlled process. Consistent attending with inconsistent responding would produce an automatic response that keeps the driver from missing changes in traffic signals. In addition, having developed an automatic response to detect light changes, the driver need not utilize limited controlled processing resources for monitoring traffic lights to determining whether they change.

In summary, our research suggests that the criterion of consistency, while 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. In this way, processing resources need not be expended on consistent elements of the task; thus, efficient complex task performance can be facilitated by allowing resources to be used on the effortful inconsistent task components.

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Figure Captions

Figure 1. Representation of a trial sequence. See text for explanation.

Figure 2. 2(a) represents training data. Numbers on the abscissa represent groups of training blocks (12) prior to each intervening test. 2(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.

Figure 3. Correct trial RT data from the intervening test blocks. Note, consistent and inconsistent responding refer to type of responding during training.

Footnote

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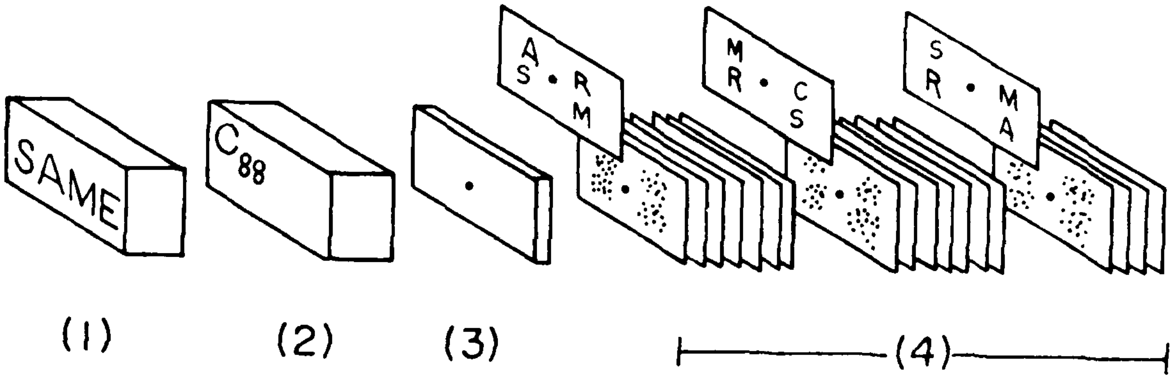

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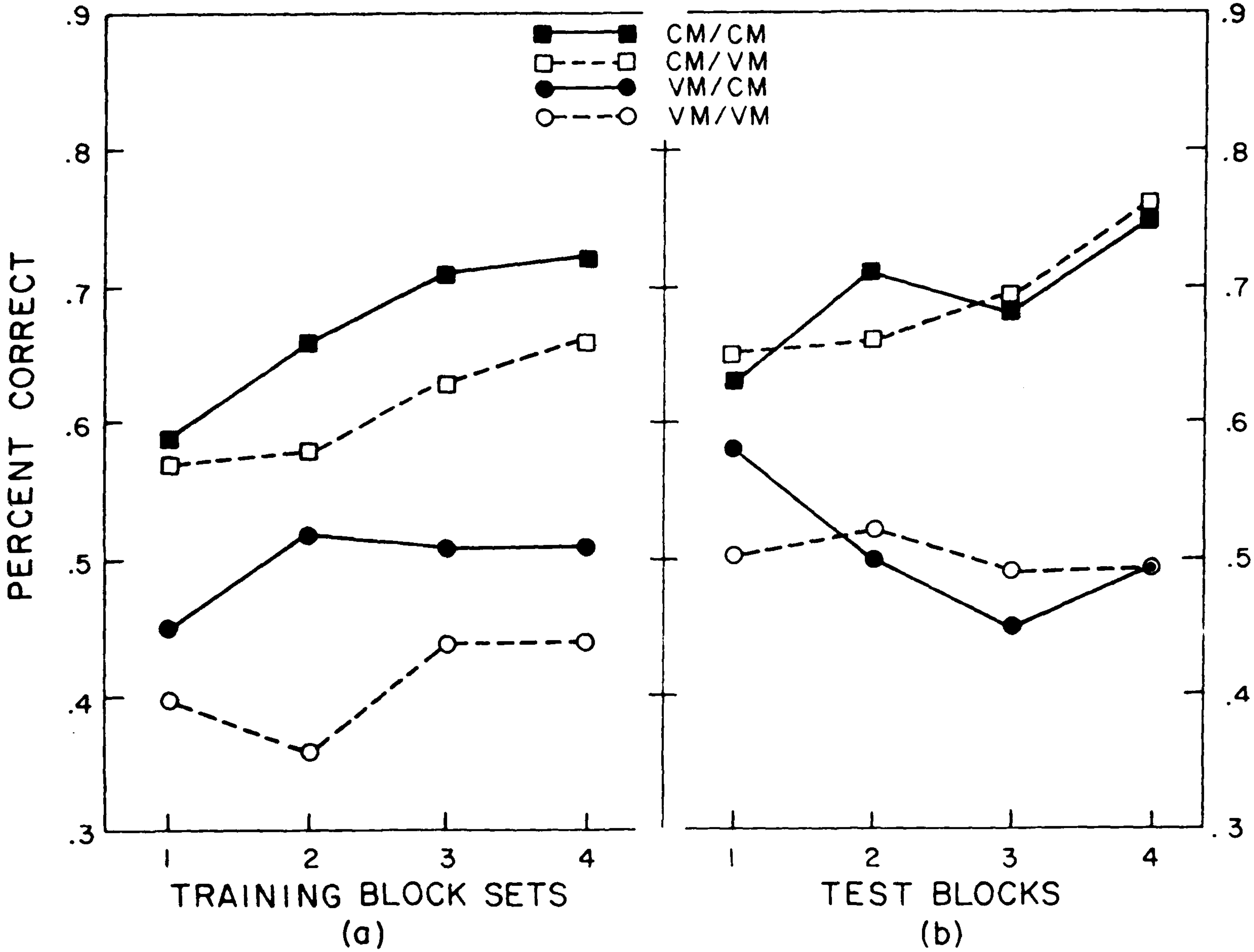

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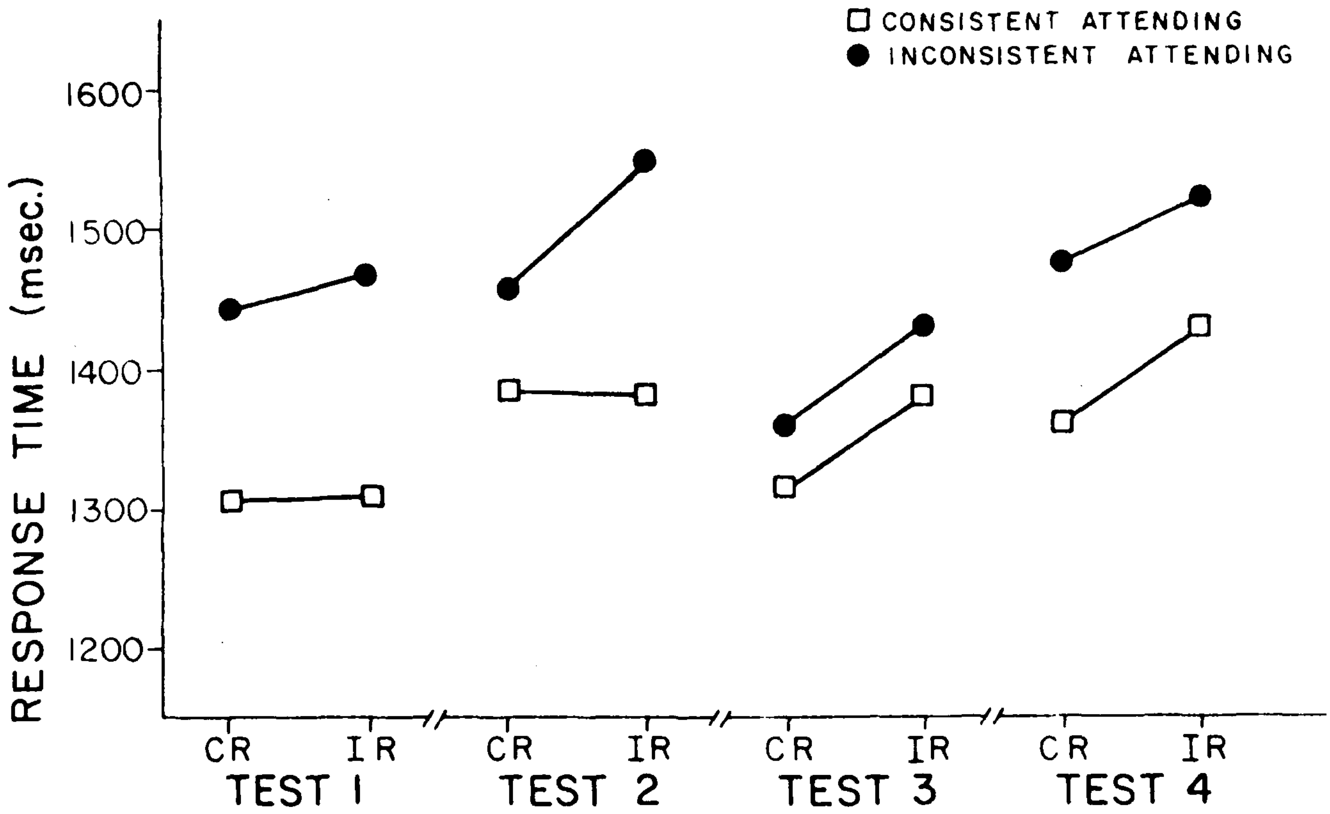

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