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DEGREE OF CONSISTENT TRAINING AND THE DEVELOPMENT OF AUTOMATIC --ETC(U)
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DEGREE OF CONSISTENT TRAINING AND THE DEVELOPMENT OF AUTOMATIC PROCESSING

Walter Schneider and Arthur D. Fisk

REPORT No. 8005

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This research was sponsored by the Personnel and Training Research Programs, Psychological Sciences Division, Office of Naval Research, under Contract No. N00014-78-C-0012. Contract Authority Identification No. NR 150-409.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 8005	2. GOVT ACCESSION NO. AD-A084 150	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Degree of consistent training and the development of automatic processing.		5. TYPE OF REPORT & PERIOD COVERED Technical Report.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Walter Schneider [redacted] Arthur D. Fisk		8. CONTRACT OR GRANT NUMBER(s) N000 14-78-C-0012
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Psychology University of Illinois		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 150-409
11. CONTROLLING OFFICE NAME AND ADDRESS Personnel and Training Research Programs Office of Naval Research Code (458) Arlington, VA 22217		12. REPORT DATE Febr[redacted]80
		13. NUMBER OF PAGES 23
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This work was also supported in part by NIMH grant number 5 R01 MH 31425.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

attention, dual task, secondary tasks, target detection, visual perception, learning, overlearning, automatic processing, control processing.

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

Consistent mapping (CM) versus varied mapping (VM) relationships between target and distractor stimuli have been shown to yield qualitatively and quantitatively different modes of information processing. Experiments utilized a multiple frame target detection search paradigm in which subjects were to detect single character targets in rapidly presented characters on a number of channels. Three experiments examined how varying degrees of consistency influenced the development of automatic processing. The degree of consistency (over)

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S/N 0102-LF-014-6601

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20. was varied by the frequency with which a letter was a target versus a distractor in a block of trials. The ratios examined were 10:0, 10:5, 10:10, 10:20, and VM (9:61). Experiments showed that automatic processing development was a monotonically increasing function of consistency. When a stimulus is a target half as often as it is a distractor (CM 10:20) the development of an automatic process was inhibited. In an experiment in which subjects were required to perform dual task automatic and control processing, automatic detection performance was a function of the degree of the consistency during previous training. The CM 10:20 detection was at chance when it was a secondary task. In addition, the functional relationship between detection accuracy and training consistency was present in the dual task conditions throughout dual task training. The data from all three experiments are discussed in terms of a strength model. The applied value of automatic processing is discussed in light of the present findings that CM training to develop automatic processes generalizes to stimuli which have a high probability of being a target. The importance of the degree of consistency to dual task situations and a variety of learning paradigms is discussed.

Degree of Consistent Training and the Development of Automatic Processing

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Report 8005

Human Attention Research Laboratory

University of Illinois

February 9, 1980

Abstract

Consistent mapping (CM) versus varied mapping (VM) relationships between target and distractor stimuli have been shown to yield qualitatively and quantitatively different modes of information processing (Schneider and Shiffrin, 1977). Experiments utilized a multiple frame target detection search paradigm in which subjects were to detect single character targets in rapidly presented characters on a number of channels. Consistent mapping conditions lead to the development of automatic processing. Three experiments examined how varying degrees of consistency influenced the development of automatic processing. The degree of consistency was varied by the frequency with which a letter was a target versus a distractor in a block of trials. The ratios examined were 10:0, 10:5, 10:10, 10:20, and VM (9:61). Experiment 1 showed that after over 1000 trials of practice the 10:20 condition did not differ from the VM condition and all other conditions were significantly better than the VM condition with performance being a monotonically increasing function of consistency. Experiment 2 was a replication of Experiment 1 except the subjects were given 12 hours of training. The data confirmed the results of Experiment 1 showing that when a stimulus is a target half as often as it is a distractor the development of an automatic process is not simply slowed, it is inhibited. Experiment 3 employed a dual task procedure. This experiment used the subjects from Experiment 2 and found almost no detections of the previous 10:20 condition stimuli in dual task search (5 percent corrected detections) early in the experiment. The previous inconsistent conditions (from Experiment 2) were consistently mapped in Experiment 3 and all conditions improved as the experiment progressed; but, differential dual task ability across the previously trained CM conditions remained throughout the experiment. In addition, the functional relationship between detection accuracy and consistency found in Experiment 2 was present in the dual task conditions throughout Experiment 3. The data from all three experiments are discussed in terms of a strength model. The applied value of automatic processing is discussed in light of the present findings that CM training to develop automatic processes generalizes to stimuli which have a high probability of being a target. The importance of the degree of consistency to a variety of learning paradigms is discussed.

Current thinking in cognitive psychology views human information processing as composed of two qualitatively different modes of processing (LaBerge, 1973, 1975, 1976; Posner and Snyder, 1975; Norman, 1976; Shiffrin and Schneider, 1977; Logan, 1978, 1979; Hasher and Zacks, 1979). In this paper we will refer to these two modes as controlled and automatic. Controlled processing requires little training to initiate, is easy to modify but slow, effortful, serial in nature, and highly dependent on load. Automatic processing is a very fast, effortless, parallel processing mode which occurs after subjects are extensively trained at dealing with stimuli in a consistent manner.

It has been shown that an automatic process will develop with a consistent mapping of stimulus to response (see Schneider and Shiffrin, 1977; Logan, 1979). Taking visual search as an example, a consistent mapping training procedure requires the target and distractor stimuli to be drawn from disjoint sets. That is, the targets only occur as targets and never as distractors and items used as distractors never occur as targets. Controlled processing must be employed when the relationship between targets and distractors is varied in its mapping. That is, for the varied mapping procedure the target and distractors are randomly chosen from the same set with stimuli sometimes occurring as targets and sometimes as distractors.

An important question that has not been systematically addressed concerns the effect of varying degrees of consistency on the development of an automatic process. The first experiments by Neisser (1963) demonstrated substantial improvement in detection performance over days of practice. Such improvement does not occur in varied mapping conditions (see Schneider and Shiffrin, 1977, p. 15-17; Rabbitt, 1978; Logan, 1979). There has been however no parametric study of the effects of the degree of consistency in visual search paradigm (see Discussion for literature from other paradigms). The purpose of the present series of experiments is to examine the effects of inconsistency, ranging from complete consistency to the truly varied mapping described above, on the development of automatic processing. The following experiments attempt to determine what degree of inconsistency will yield performance equivalent to controlled processing. In addition, the cost associated with various degrees of inconsistency is examined.

Dumais (1979) presents data which suggest that subjects can automatically detect items by both attending to targets and by ignoring distractors. She proposed a model in which the strength (defined as the tendency of an item to draw attention) is primarily determined by the consistency of training. Consistently mapped items that always occur as targets and never as distractors develop the greatest strength. Items that are varied in their mapping develop some intermediate strength with a target item (on a given trial) having an equivalent tendency to draw attention as the distractors.

Taking the work of Dumais (1979) into account, one would expect an inverse relationship between performance and inconsistency. There exists no data that will allow a statement concerning expected performance levels given particular degrees of consistency (or inconsistency). Further, no data are available to indicate the weakening effect relative to the strengthening effect of an item's occurrence as a distractor versus a target, respectively. For example, is the strengthening effect of an item's detection (as a target) equally cancelled by its occurrence as a distractor or is there more gain associated with a detection than cost of being a distractor?

The following three experiments examined how varying degrees of consistency influenced the development of an automatic process. Experiment 1 gave subjects approximately 1000 trials of practice. Experiment 2 was a replication of Experiment 1 except approximately 6000 trials of practice were given to the subjects. Experiment 2 examined whether or not certain degrees of inconsistency simply slowed the development rate of an automatic process or actually inhibited it. Experiment 3 employed a dual task paradigm as an additional measure of the development of automaticity of the experimental conditions used in Experiment 2.

General Method

This section describes details common to all the experiments. Departures from and/or additions to the general method will be described with each experiment.

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 602 cathode ray scopes which contained P-31 phosphor. Each subject wore a headset through which white noise (80 db) and an error tone were carried.

Stimuli. The characters used in the present experiment were 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 an average of 43 dots used to specify a character. The characters were .52 degrees in width by .58 degrees in height. The refresh rate of the dots making up the stimuli was 10 msec. 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. From center fixation to the center of each letter subtended a visual angle of one degree. The subjects sat 45 cm from the display. The characters used were: A, C, D, E, M, R, S, U, and Z. These letters were chosen (through pilot testing) such that each letter was approximately equally confusable with the other letters.

Design and Procedure. The primary independent variable manipulated in the following experiments was the degree of consistency of a letter appearing as a target or a distractor. In the completely consistent condition the memory and distractor sets were disjoint; that is, a character used as a target in the completely consistent condition was never a distractor. In the varied mapping condition the targets and distractors were randomly chosen from the same character set. In the other conditions, the character used in a given degree of consistency condition occurred as a distractor a fixed number of times per block. The actual number of occurrences as distractors for these non-consistent conditions will be presented with each experiment. The completely consistent condition is denoted as CM, the varied mapping as VM, and the conditions of varying degrees of consistency are symbolized as "CM" (t:d), where t=number of times a target (per block) and d=number of times a distractor (per block).

Subjects searched for one character (memory set size one) in frames each containing four characters in Experiments 1 and 2. Memory set size was one and frame size was four in all the experiments. Experiment 3 utilized a frame size of 3 and a memory set size of 1, 2, or 5. A within subject design was used for all experiments.

Trial Sequence. For all of the experiments, each trial consisted of the following sequence. 1) The memory set display. This display was presented with the target item (memory set size was one) in the upper left hand corner of the scope. In addition, accuracy feedback was presented in this display and will be described below. The subjects were given up to 30 seconds to study the target item and initiate the trial sequence, i.e., terminate the memory set display. The subjects initiated the remaining part of the trial sequence by a button push with the index finger of their left hand. 2) 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. 3) 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 dot masks were presented for 30 msec in the same display positions as the letters. These elements (letters and masks) 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. A set of four distractor letters was used for all 12 frames. The letters were randomly arranged with the restriction that no letter could appear in the same position on two successive frames.

In all experiments the target item was presented once during the frame sequence. The target could occur during frames 3-11. The target frame as well as the display location of the target within that 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 and represented a one-to-one mapping of display position to response button. The subjects were instructed to "guess" the correct response at the end of the frame sequence if no target was detected.

Feedback. Performance feedback was given to the subjects and consisted of two types: 1) Error feedback. This consisted of a tone burst given through the subject's headset. The error feedback was given when the subject incorrectly indicated the target's display position. 2) Accuracy feedback. This feedback consisted of three separate types. First, when the subject correctly indicated the target's location a random dot pattern would appear to spin off the screen from the target's location. Second, the subject's current accuracy, indicated by a two digit number, was presented along with the memory set display. Third, a "skill" rating, which corresponded to a given accuracy level, was given to the subject by blinking one of four colored LED's on the subject's response box. The ratings and the accuracy level needed were: 100-90, Ace (green LED); 89-80, Expert (yellow LED); 79-60, Average (red LED); 59 & below, Novice (red LED). The skill ratings were printed below the corresponding LED's. Both the accuracy and the "skill" rating were initialized to zero at the beginning of each trial block.

VM Practice. Prior to participating in the experiments, subjects were given 150 trials of just VM practice. The selection of letters was such that the subjects had no exposure to any letters subsequently used as CM items (CM or "CM" (t:d)) in the experiment proper. The VM practice set letters were used as the VM set in the rest of the experiment.

Experiment 1

Method

Subjects. Eighteen subjects from the University of Illinois introductory psychology pool were used in the experiment. Participation in the experiment paritially fulfilled a course requirement. All subjects were right handed, reported normal or corrected to normal 20/20 vision and reported English as their native language.

Design and Procedure. The experiment was divided into a "training" phase and a "test" phase. The "training" phase utilized four CM items (one per CM condition), one item was consistently mapped and three were inconsistently mapped to varying degrees. The remaining five letters were used as VM items. Table 1 specifies the four CM conditions and the VM conditions on a per block basis. Each CM item occurred as a target 10 times. The row labeled "frequency as a distractor per block" refers to the number of trials the correpsonding letter (either CM or VM conditions) occurred as a distractor. If a CM item occurred as a distractor it and a set of three VM letters were presented once on every frame of the trial. Two CM items could not occur as distractors during the same trial. CM letters appeared as distractors only during VM trials. During VM trials without "CM" distractors and "CM" trials four of the five letters were used for distractors in the 12 frames. There were 85 trials per block with the subjects completing 12 trial blocks (1020 trials) prior to the test phase of the experiment.

The test phase was included to test the development of automatic processing subsequent to training with varying degrees of consistency. The test was one block of 100 trials. There were 20 trials per CM condition and 20 trials of VM. During the test none of the CM items functioned as distractors.

Results and Discussion

The data gathered during the training phase of the experiment are presented in Table 1. This table represents the percentage of correct position detections across the five training conditions. (Note, the VM trials which contained CM distractors were excluded from the VM data in the table since the VM condition was included to represent baseline controlled processing performance.) The data are corrected for guessing in all cases (corrected probability equals probability of a detection minus one-third probability of an error).

Insert Table 1 about here

Table 1

Experiment 1

	CM1	"CM"2	"CM"3	"CM"4	VM
Frequency as a distractor per block	0	5	10	20	61
Training Detection Accuracy					
Blocks 1-4	.56	.50	.48	.49	.45
Blocks 5-8	.57	.56	.54	.54	.50
Blocks 9-12	.60	.60	.53	.54	.49
Average	.58	.55	.52	.52	.48
Test Detection Accuracy	.72*	.69*	.63*	.61	.51

*significantly different ($p<.01$) from VM

Table 1 shows that all of the conditions improved during training with the CM1 (10:0) and "CM2" (10:5) conditions showing the best performance at trial blocks 9-12. The CM items occurring as distractors did not differentially affect VM performance. An examination of Table 1 reveals that the rank ordering of conditions at trial blocks 9-12 and the test are the same. An analysis of variance performed on the test data (experimental conditions X subjects) confirmed that the main effect of experimental conditions was significant; [$F(4,68)=2.69$, $p<.04$]. The post hoc comparisons indicated that the CM1 (10:0), "CM2" (10:5), and the "CM3" (10:10) conditions significantly differed from the VM (9:61) condition ($p<.05$)[1]. The "CM4" (10:20) condition was more variable across subjects than the other conditions and did not differ from the VM condition ($p>.1$). Although the rankings of the CM conditions are consistent with expectations of the effect of the varying degrees of inconsistency, statistically the CM conditions did not differ ($p>.2$).

The present experiment was successful in showing differences between CM conditions as inconsistency is varied. The performance of the "CM4" (10:20) condition did not statistically differ from performance expected when controlled processing must be employed (VM condition) and the "CM3" (10:10) condition was only marginally significant. There are aspects of the data that are bothersome; specifically, none of the CM conditions differed in a statistical sense. Also, with the statistical analysis put aside, all CM conditions did differ from the VM condition in terms of percent correct position indication. This may indicate that, with the present degrees of inconsistency, all CM conditions will develop to the same performance asymptote level, but, the inconsistency slows the development rate.

The next experiment tested the above suggestion and examined two additional alternative hypotheses. These were: 1) some amount of time is required for the CM inconsistencies to disrupt the system and 2) inconsistency may be handled by an automatic process but will not allow the development of an automatic attention response.

Experiment 2

Method

Subjects. Five females and four males were paid for their participation in the present experiment. All subjects were students at the University of Illinois. One subject was left handed; therefore, she initiated each trial with the index finger of her right hand and indicated the target's location with the index finger of her left hand.

Procedure. The present experiment was a replication of Experiment 1 except it ran for a longer duration. All subjects completed 6 of the training/test cycles described in Experiment 1.

Results and Discussion

The data from the training part of the training/test cycles are presented in Figure 1. (The lines are not connected in this figure indicating the occurrence of the intervening tests). It is clear from Figure 1 that all of the conditions showed some improvement with time. The CM1 (10:0) and "CM2" (10:5) condition showed the largest amount of increase in ability to correctly indicate the target's position. The "CM4" (10:20) and VM conditions did not appear to differ substantially from each other throughout the experiment. Finally, the "CM3" (10:10) condition generally maintained a "middle range" performance level throughout the experiment. As in the previous experiment, the "CM" distractors did not significantly affect VM detection accuracy.

Insert Figure 1 about here

The data gathered during the intervening tests of automatic processing development are presented in Figure 2. An analysis of variance (experimental conditions X time (intervening tests) X subjects) was performed on the transformed (Arcsin) accuracy data. The main effects of experimental conditions and time reached statistical significance; [$F(4,32)=4.13$, $p<.009$] and [$F(5,40)=5.6145$, $p<.001$], respectively. The experimental conditions X time interaction also was significant; [$F(20,160)=1.9146$, $p<.015$]. The analysis of simple main effects revealed substantial differences between conditions from test number four on, $p<.001$ in all cases. Also, the only experimental condition being significantly effected by time was the CM1 (10:0) condition, [$F(5,40)=16.66$, $p<.0001$]. Post hoc comparisons [2] of the averaged performance of tests 5 and 6 between the conditions showed that only the "CM4" (10:20) condition did not differ from the VM condition ($F<1$). The CM1 (10:0) condition statistically differed from both the "CM3" (10:10) and "CM4" (10:20) conditions. The CM1 condition did not statistically differ from the CM2 condition ($p=.11$). The CM2 condition did not differ from the "CM3" condition and the difference between the CM2 and "CM4" condition was marginally significant [$F(1,8)=5.09$, $p=.053$]. Finally, the "CM3" condition did not differ from the "CM4" condition.

Insert Figure 2 about here

The data are plotted in Figure 2 to show the functional relationship between degree of consistency and percent correct position indication. Points are plotted as a function of the number of times a letter appears as a distractor per ten times as a target during training for the "CM" conditions. The data show detection improvement in the completely consistent condition, CM1 (10:0), relative to the other conditions. It is important to remember that the conditions in tests 1-2 do not statistically differ but by tests 5-6 the differences were present (see above).

The data of the present experiment demonstrated that even with 10 hours of training the performance of the "CM4" (10:20) condition did not differ from that expected with VM (9:61) controlled processing. This disconfirms the hypothesis that inconsistency just slows the development of an automatic process. It seems safe to say that when an item is searched for as a target half as often as it is a distractor it will require controlled processing for its detection. The observer seems able to deal with some inconsistency and still perform better than expected if VM controlled processing were required to perform the detection task. Note the VM tests did not show significant improvement during the test

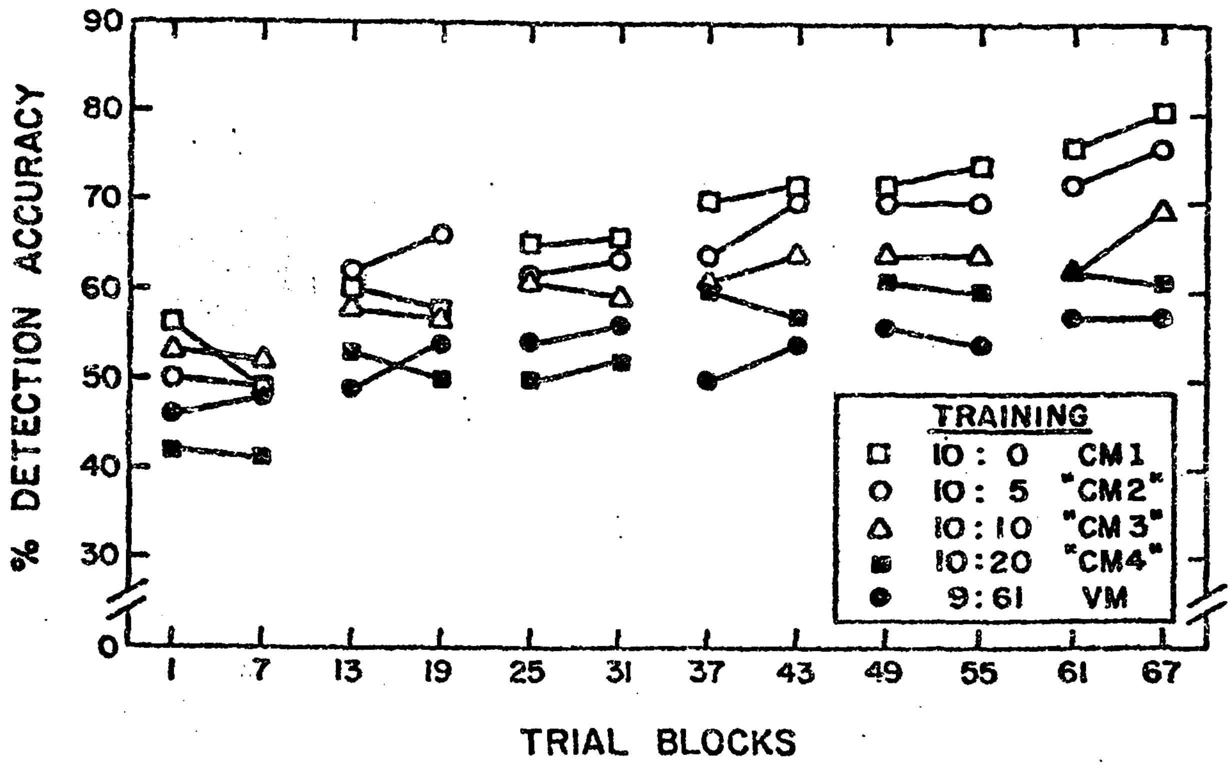

Figure 1. Experiment 2 training corrected detection accuracy as a function of training blocks (85 trials per block). After every twelfth block of training a test block occurred. Each point represents the data from six blocks.

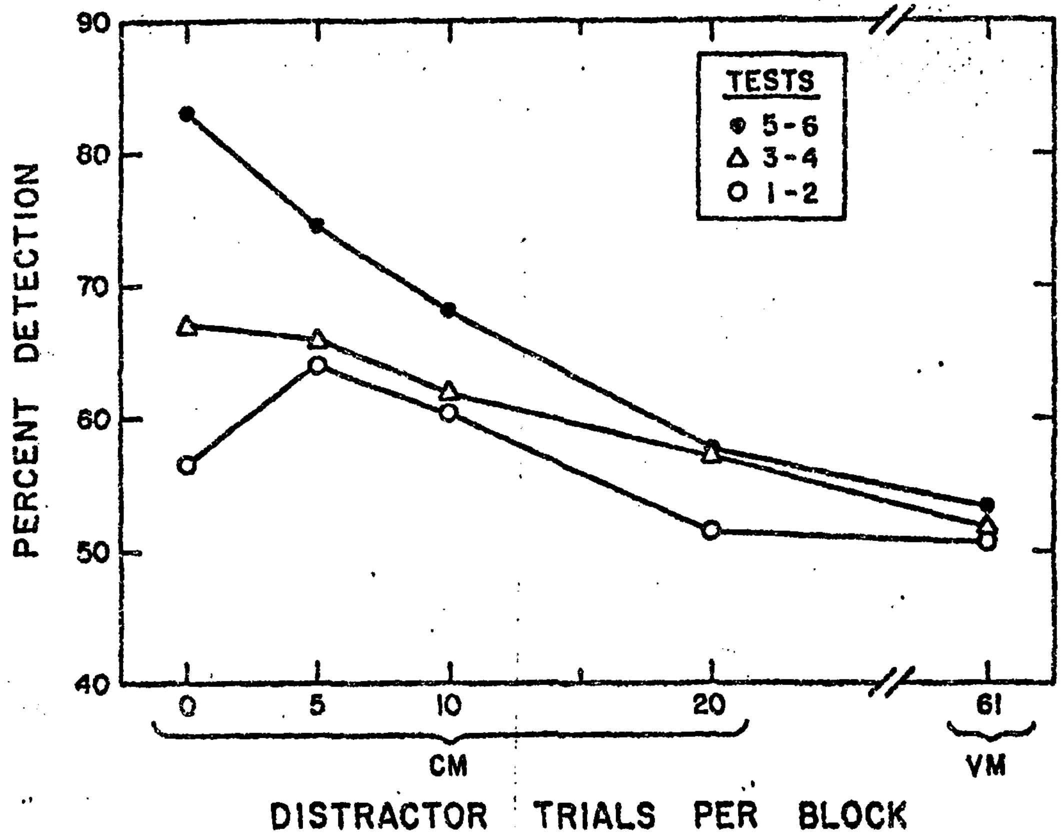

Figure 2. Experiment 2 corrected detection accuracy as a function of distractor frequency at different levels of CM training.

sessions. Figure 2 does show a functional relationship between consistency and accuracy. The slope of the line for tests 5-6 is negative indicating increasing cost of accuracy as consistency is decreased.

Schneider and Fisk (1980) reported that, given sufficient training, subjects were able to perform a controlled and automatic search task simultaneously without a sensitivity deficit to either task. This type of dual task methodology allows accessing the amount of automatic processing development by removing controlled processing. The following experiment uses a dual task in order to measure the degree to which subjects can automatically process target items from the various training conditions of the previous experiment.

Experiment 3

Method

Subjects. The subjects who participated in the previous experiment were employed in Experiment 3.

Procedure. The present experiment used the CM stimuli that had been trained in the previous experiment and employed the same VM stimuli. All previously trained CM items were consistently mapped in the present experiment. As in the previous experiments, only one target could occur in each trial. There were three basic conditions in the experiment with "condition" information contained in the memory set display. These conditions were: 1) Single target (single task) - one memory set item was presented and the subject's task was to detect this item in the upcoming frame sequence. 2) Dual VM target (dual task) - two VM letters were presented in the memory set display. One of these letters occurred as a target in the frame sequence. 3) Dual VM/CM (dual task) - in this condition the memory set display contained one VM letter and a dot mask to the right of the VM letter. This indicated to subjects that the VM item may appear or any one of the four previously trained CM items may occur during the frame sequence. For this condition the subjects were instructed to protect their VM performance. They were told, "If you were being paid based upon your detection accuracy, you would be paid conditional on your VM accuracy in this condition." In the dual VM/CM condition only the VM performance entered into the performance feedback. This was meant to clearly emphasize the VM search. For the dual VM/CM trials VM targets occurred 50 percent of the time while each CM letter occurred on 12.5 percent of the trials. (Each block of trials contained 32 VM/CM trials, 16 of which contained the VM target item with 4 trials allocated to each CM target.) During the first five blocks of trials the subjects were given a card containing the four CM items.

Accuracy feedback was given to the subjects with their average accuracy being displayed as described in the General Methods for the single task condition. For the dual task trials the VM average accuracy was displayed below and to the right of the rightmost memory set character. The separation between the rightmost memory set character and the leftmost number of the accuracy was approximately 2 degrees.

The experimental conditions were manipulated between trials. There were 60 trials per block. Each of four CM letters occurred as a target in the single task condition four times and as a dual task target four times. Each of five VM targets occurred on four VM single task trials, 16 VM target trials in the VM/CM condition and 8 VM (M=2) trials. Due to a limitation of number of characters for the VM (M=2) condition, frame size was reduced to three for all conditions. A random dot mask was used as a "place holder" and its display location was randomly determined for each frame.

Results and Discussion

Figure 3 presents the data from Experiment 3. This figure plots performances as a function of previous CM training and the relevant VM conditions. The performance of the single conditions was averaged over the entire experiment giving rise to one point per single condition. The dual task conditions are plotted to show the family of curves created as subjects became better at dual tasking.

Insert Figure 3 about here

An analysis of variance (experimental condition X time X subjects) was performed and revealed a significant main effect of experimental conditions [$F(10,80)=13.2$, $p<.001$] and a significant main effect of time (trial blocks in groups of 5) [$F(7,56)=9.16$, $p<.001$]. The experimental condition X time interaction was also significant [$F(70,560)=2.0$, $p<.001$]. An analysis of the simple main effects found that, for the single task conditions, only the CM3 (previous 10:10 condition) changed over time, [$F(7,56)=2.8$, $p<.02$]. In addition, all CM dual task conditions improved over time ($p<.001$ in all cases). The VM dual conditions (i.e., VM (M=2) and VM in the VM/CM condition) remained stable throughout the experiment ($F<1$ in both cases).

The above analysis confirms what is apparent from examining Figure 3. That is, the source of the significant experimental condition X time interaction is the stability of the single task and VM dual performance and the increasing ability to perform in the CM dual task condition. The interaction is not due to time (practice) differentially affecting the subjects' ability to detect the various CM targets. It is not surprising that the subjects were unable to overcome the effects of the previous inconsistent training (of the CM conditions) since they were only given 480 trials of the single task for each condition. This is where improvement would occur; but, there were simply not enough trials in the present experiment to overcome the 6720 trials (per condition) of the previous inconsistency. Note when subjects began the dual task (blocks 1-5) the CM4 performance was near chance (5%). This supports the earlier conclusion that a 10:20 training ratio is effectively VM and results in no automatic attention response development. The improvement in all the present conditions is assumed to be due to the now pure CM training all the CM conditions receive, and experience in performing the dual task search (see Schneider and Fisk, 1980).

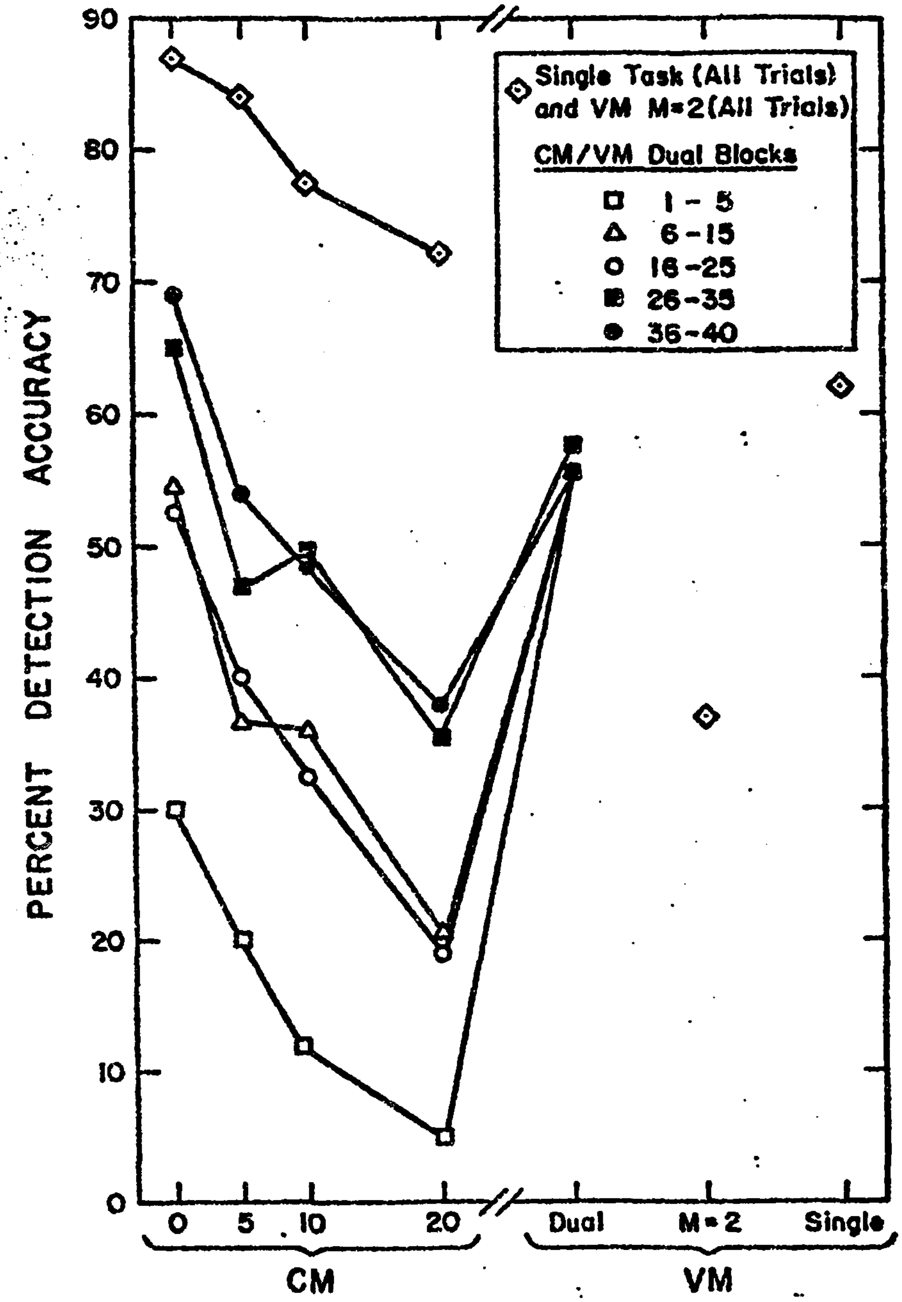

Figure 3. Experiment 3 single and dual task performance as a function of previous CM training. CM letters never appeared as distractors in this experiment. The CM conditions are plotted as a function of previous CM training frequency of occurrence as a distractor (see Figure 2).

The present experiment has been effective in showing differential dual task detection ability across the previously trained CM conditions. There was an inverse relation between detection accuracy and previous consistency with the relationship being stable over the experiment.

General Discussion

The present experiments have demonstrated that detection accuracy in a visual search task is a monotonically increasing function of consistency. The experiments have shown that VM controlled processing is expected when a stimulus item is dealt with as a target half as often as it is a distractor. Experiments 1 and 2 showed that when the probability of a stimulus being a target or distractor is equal only a slight benefit (over VM training) is expected. In the dual task experiment both the previous 10:10 and 10:20 conditions were near chance (12 and 5 percent detection, respectively). The dual task detection performance of the 10:10 condition was equivalent to performance of unemphasized dual VM performance reported by Schneider and Fisk (1980, Experiment 8). This suggests that neither the 10:10 nor the 10:20 conditions benefited from CM training in terms of showing even rudimentary automaticity. In an experiment similar to Experiment 1 we found no differences between search conditions 10:0, 10:1, and 10:2.[3] This suggests that there may be some saturation of the effect of degree of consistency at near perfect consistency.

The degree of automatic processing development detection data shows an exponential function of the frequency with which an item appeared as a distractor. Decreasing the consistency of an item below some consistency threshold has little effect (no significant differences between 10:20 and 9:61). Increasing the consistency of an item between 10:20 and 10:0 improves automatic process development. Previous results suggest that the automatic process development rate increases little between 10:2 and 10:0 (see footnote 3) suggesting a saturation of automatic process development. These characteristics of a consistency threshold, a potentially logarithmic function of the degree of consistency, and a saturation of consistency may be predictable by mass action neural models (e.g., Anderson, Silverstein, Ritz, and Jones, 1977). Later reports will present models for interpreting and predicting the effect of the degree of consistency.

The benefits of consistent mapping training (leading to subsequent automatic processing development) generalize to situations in which there is less than perfect consistency. There was significant improvement over VM performance when a letter appeared equally often as a target or distractor (10:10). This suggests that automatic processing might best be viewed as a graded rather than an all or none influence. Hence automatic processing concepts should generalize to situations which have highly probable responses.

The degree of consistent mapping training is particularly important in dual task situations. The ability of subjects to perform the automatic process secondary task was a direct function of previous consistency of training (Experiment 3). Dual task performance was not simply a function of training trials (since all CM conditions had equal numbers of target trials). This suggests that in environments in which operators must perform multiple tasks it is critical to structure the training, task demands, and instrumentation to enable consistent responding and the development of automatic processing.

These data may be interpreted in terms of a strength or accumulation model. Dumais (1979) presents data which indicate that detection performance is determined by the strength of the target relative to the distractors. The notion of a gain in strength, i.e., tendency of a stimulus to draw attention, due to its occurrence as a target and a decrement in strength when that stimulus is a distractor applies to the present data. There does not appear to be a one-to-one relationship between the gain of a stimulus' detection as a target and the cost of its occurrence as a distractor.

The degree of consistency is a critical parameter for the development of automatic processing and appears to be a central concept in learning. In concept learning inconsistent feedback (referred to as Misinformation) results in effectively no learning when Misinformation occurs on over 30 percent of the trials (Pishkin, 1960; Rogers and Haygood, 1968). Exposure to random (inconsistent) reinforcement can considerably slow the learner in concept formation (Trabasso and Staudenmayer, 1968). Cue differentiation in multiple cue discrimination learning is a function of cue validity (Friedman, Trabasso, and Mosberg, 1967). In single cue probability learning subjects fail to identify consistent relationships when stimuli show low ($r<.30$) correlations to criterion responses (Brehmer, 1978; Johansson and Brehmer, 1979). In free recall the concept of subjective organization (Tulving, 1966) suggests that learning is a function of degree to which subjects can organize the list (see Crowder, 1976, for discussion). In digit series learning, a lack of consistency of grouping results in no transfer between list repetitions (Bower and Winzenz, 1969; Johnson and Migdoll, 1971). In animal discrimination learning, the probability of attending to a stimulus dimension is a function of the consistency with which attending to that dimension results in consistent reinforcement (Sutherland, 1964; Mackintosh and Holgate, 1968). Learning a complex skill such as reading seems to be influenced by consistency. Illiteracy rates in developed countries suggest the importance of consistency in learning to read. Bouwhuis (Note 1) reports the illiteracy in English speaking countries (United States and England) are about twice that of non English speaking countries with comparable levels of industrial development and commitment to education (Germany, Denmark, Belgium, Netherlands, Spain, Italy). Bouwhuis suggests this difference is due to the lack of phonetic consistency of English. The present work shows that as consistency decreases, the effectiveness of automatic processing decreases. Hence users of phonetically inconsistent languages should have more difficulty becoming automatic word encoders. All these results show learning is not a function of reinforcements but rather a function of consistent reinforcements. Automatic processing develops when subjects deal with information in a consistent manner. As the degree of consistency declines, the effectiveness of automatic processing declines, and control processing becomes necessary.

Reference Notes

1. Bouwhuis, D. Personal communication, April 1980. Some of the relevant data is included in his Doctoral dissertation "Visual Recognition of Words", University of Nijmegen, 1979.

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Footnotes

[1] The F ratios were: CM1-VM, $F(1,17)=9.347$; CM2-VM, $F(1,17)=9.857$; CM3-VM, $F(1,17)=4.44$.

[2] The F ratios for the significant CM and VM comparisons were: CM1-VM, $F(1,8)=23.179$; "CM2"-VM, $F(1,8)=35.33$; "CM3"-VM, $F(1,8)=26.44$. F ratios for CM1-"CM3" and CM1-"CM4" comparisons were: $F(1,8)=6.2328$ and $F(1,8)=19.1936$, respectively.

[3] Data from an earlier study indicated there was no difference (in automatic processing development) between the completely consistent condition (10:0) and experimental conditions in which either an item occurred as a distractor once (10:1) or twice (10:2) per block. The detection test performance after 1044 total training trials were respectively .69, .66, .70. With additional training the 10:0 condition may have been better than the 10:2 condition but we assume the differences would have been small.

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