Iconic memory and central processing capacity*

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Three experiments were conducted to assess whether or not iconic memory is influenced by demands placed upon central processing capacity. In Experiment 1 S was required to store material in short-term memory while performing an iconic memory task. In Experiments 2 and 3 S performed an auditory classification task concurrently with iconic storage. The three experiments did not reveal any significant impairment of iconic memory as a function of performing a subsidiary task. Similarly, performance on the subsidiary tasks did not suffer as a result of the concurrent iconic memory task.

Neisser (1967) has applied the term iconic memory to the variety of visual information storage investigated by Sperling (1960). As Sperling demonstrated, visual information can be stored in a relatively uncategorized labile form for several hundred milliseconds prior to transfer to a more limited but more persistent short-term memory (STM) system. Recently, several investigators have studied STM in the framework of the proposition that STM requires a portion of S's limited information-processing capacity (see Broadbent, 1958; Posner, 1966; Moray, 1967). Posner and Rossman (1965), Posner and Konick (1966a), and Dillon and Reid (1969) have demonstrated that forgetting in STM is directly related to demands placed on central processing capacity (CPC). The procedure to demonstrate this relation manipulates the information reduction required by a subsidiary task performed by S during the retention interval of an STM test. The question can be raised, therefore, as to what extent iconic memory as a form of retention is influenced, like STM, by demands on CPC.

The present series of experiments make processing demands on S during an iconic memory task in order to see if such demands will have a disturbing effect on the accuracy of report of iconic material. If iconic memory is dependent on CPC, a decrement in recall performance would be expected. On the other hand, if iconic memory is "peripheral" and relatively independent of other more central stores and processing systems, then demands on the limited CPC should have little or no effect. The latter result would suggest that the icon passively decays and is not contingent on active investment of processing energy. An observation of this nature has been reported for the short-term retention of kinesthetic information (Posner & Konick, 1966b; Williams, Beaver, Spence, & Rundell, 1969).

*This report is based on a thesis submitted by the first author in partial fulfillment of the MA degree at the University of Connecticut under the direction of the second author. The authors would like to thank Herbert Cross for his assistance in the preparation of the manuscript.

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EXPERIMENT 1

In the first experiment, the Sperling (1960) task was interpolated between the presentation of a consonant or digit trigram, which S read aloud, and its recall. The Sperling task entails the delayed partial sampling of a tachistoscopically presented array of items and serves to operationally define brief visual or iconic memory as referred to in the present series of experiments. It has been argued (Turvey, 1967) that the Sperling paradigm studies the storage of uncategorized material, whereas the distractor technique of Peterson and Peterson (1959), used in STM experiments, studies the storage of categorized material. In the first experiment of the present investigation, the Sperling task functioned as the distractor, or interpolated activity, for the Peterson STM test. Since STM requires a portion of CPC, maintaining prior information in STM should limit the amount of processing capacity available for the Sperling task. This reduction in capacity should result in a lower level of recall and perhaps a faster decay rate of iconic information, if it is the case that iconic memory, like STM, is dependent on CPC.

Method

Subjects. Two males and two females with normal or corrected-to-normal vision served as Ss. The ages of the Ss were between 23 and 28 years. The Ss were not naive to the experiment.

Materials. Two sets of slides were made. One set consisted of 20 slides of three rows of five letters produced from a 15-letter alphabet (vowels and Q, X, Y, H, R were excluded). The letters were randomized so that no two rows were identical. The other set consisted of 30 consonant trigrams (25% association value) and 30 digit trigrams.

Apparatus. A Lafayette T-2K constant-illumination projecting tachistoscope was used to project the display slides onto the viewing screen. The presented field subtended a visual angel of 2 deg 43 min vertical x 4 deg horizontal at a viewing distance of 7.5 ft. One channel constantly projected a darkened preexposure field to reduce brightness contrast. The center of the preexposure field was marked by a faint but discernible black X. Initiation of the display and the postdisplay tone indicator sequence was by means of an S-controlled switch. The display terminated after 100 msec and was followed by one of three possible tones at one of five possible delays. The three tones were 200, 600, and 2,000 Hz and were transmitted to S by means of earphones. The five delays of the tone indicator were 0, 100, 300, 500, and 700 msec. The exposure duration, the tone delays, and the tone duration were controlled by thhree Hunter timers.

Procedure. Each S was given 3 days of preexperimental training. On Day 1 S was trained to discriminate between the three postdisplay tone indicators designated as high (2,000 Hz), middle (600 Hz), and low (200 Hz), and corresponding respectively to the top, middle, and bottom row of the 3 by 5 display. Practice in tone discrimination was given prior to every session throughout the experiment. Following identification of the tones, S, on Day 1, received 100 trials. A trial consisted of the following events. First, there was a "ready" signal spoken by E; second, S pressed the key initiating the display-tone sequence; third, S reported the row specified by the tone indicator. The mode of report required that S record as many as possible of the letters of the specified row in their correct within-row positions on a response sheet of five blocks. After responding, S turned the sheet over so that previous responses would no longer be visible to him. Within the 100 trials, tone indicators and delays were randomized, with the restriction that each delay had to occur 20 times. The three tone indicators did not occur an equal number of times at each delay.

Day 2 of preexperimental training was the same as Day 1, except that a trial now included the visual presentation of a consonant or digit trigram prior to the presentation of a 3 by 5 matrix. Both presentations were initiated by S pressing a key. On the average, across Ss, approximately 3 sec elapsed between the onset of the trigram and the onset of the matrix. The Ss were instructed to press the key for presentation of the matrix as soon as possible after the trigram presentation. On each trial S first reported the letters from the row specified by the tone indicator and then the letters or digits of the previously presented trigram. Ten practice trigrams were used, five consonant and five digit trigrams, and, as on Day 1, S was given 100 trials.

Day 3 was a repetition of Day 1, with S receiving 50 trials. The purpose of the 3 days of preexperimental training was to ensure that (1) Ss had associated the postdisplay tone indicators with their respective rows, (2) all rows of the matrix were of approximately equal availability on presentation of the tone indicator, i.e., S was not attempting to guess, and (3) practice effects would be minimal on the experimental days. Inspection of the Day 3 data indicated the decay function reported by Sperling (1960).

Subsequent to the training days, each S went through four experimental conditions on 4 consecutive days. The order of experimental conditions was counterbalanced such that each condition was given to only one of the four Ss on each of the 4 days. On each of the 4 experimental days, each S was given 20 practice trials followed by 100 experimental trials. An experiment by Turvey (1967) has demonstrated that repetition of a matrix across trials does not have any significant effect on recall of that matrix in the Sperling situation. In the Turvey experiment a matrix was repeated 54 times with only one trial intervening between successive repetitions; in the present experiment 19 trials with other matrices intervened between the repetition of a given matrix. For every session of 100 trials a 3-min pause elapsed between blocks of 20 trials and a 10- to 15-min rest interval was introduced approximately halfway through a session.

The experimental conditions can be described most suitably in terms of the sequence of events comprising a trial.

Condition E1: (1) a ready signal from E; (2) S pressed a key which resulted in the 100-msec exposure of a consonant or digit trigram that S repeated aloud; (3) S pressed the key again to display a 3 by 5 letter matrix for 100 msec; (4) following one of five delays, a tone indicator sounded specifying which row S had to report; (5) upon hearing the tone, S wrote on the available response sheet as many as possible of the letters of the specified row; (6) S then wrote down on the response sheet the letters or digits of the previously presented trigram.

Condition E2: The same as E1 except for the absence of Event 6. In this condition S was not required to retain the trigram during performance of the Sperling task.

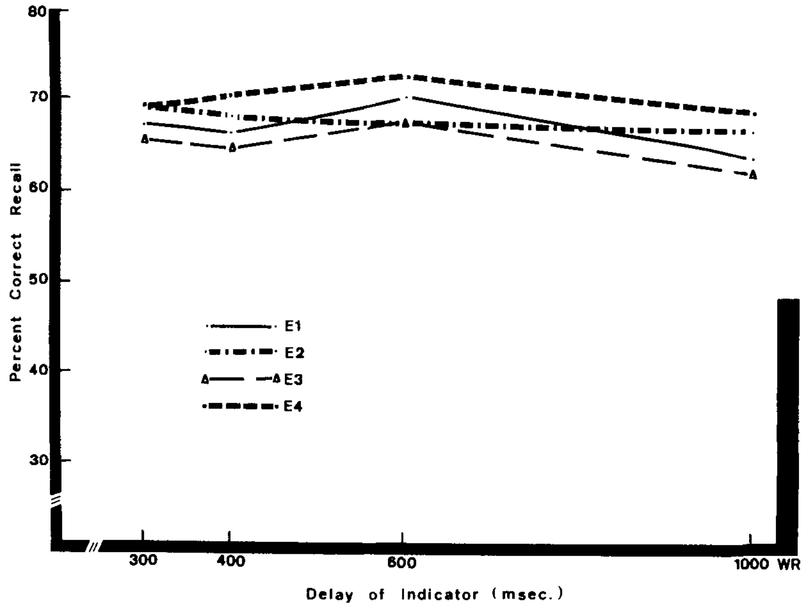

Fig. 1. Percent correct recall as a function of delay of indicator and condition foi Experiment 1.

Condition E3: The same as E1 except for the absence of Events 2 and 6. In this condition, therefore, S did not receive the trigram.

Condition E4: Involved only Event 3. The S was instructed to report as many letters from the matrix as possible immediately after the exposure; no tone indicator occurred. This condition was equivalent to the memory span technique or whole report procedure of Sperling (1960).

Each S on each trial was scored for the number of letters reported in their correct location. For the partial report conditions, the proportion of correctly recalled letters out of all the letters in the row to be selected was multiplied by the total number of letters, i.e., 15, in the matrix (see Sperling, 1960).

Results and Discussion

Means were calculated for each tone-delay combination. Figure 1 shows the percentage recall averaged across Ss for each of the five delay intervals in Conditions E1, E2, and E3. All three functions conform to the decay functions reported by Sperling (1960). Also included in Fig. 1 is the whole report baseline derived from the data of Condition E4. Observation of Fig. 1 indicates that the partial report conditions, Conditions E1, E2, and E3, yielded recall superior to that of the whole report condition.

A Treatment (Conditions) by Treatment (Delays) by Ss analysis of variance was performed on the data of Conditions E1, E2, and E3. The effect of conditions was insignificant ($F < 1$), but, as expected, the main effect of delay was significant [$F(4,12) = 8.81$, $p < .005$]. The Condition by Delay interaction was significant [$F(8,24) = 3.61$, $p < .01$]; a Tukey contrast suggested that this interaction effect was primarily due to a significant difference between Condition E1 and Condition E3 at 0-msec delay ($p < .05$).

Only one S showed a substantial number of errors in the recall of the consonant and digit trigrams. Across Ss the average recall was 2.77 items. Inspection of the E1 data revealed no difference in the retrieval of the matrix letters as a function of whether a consonant or digit trigram had preceded the matrix on a trial. This suggests that proactive interference effects were not operating within a trial. If they were, performance on the Sperling task in which letter matrices were used would have been poorer for the consonant trigram trials than for the digit trigram trials.

The results of Experiment 1 suggest that retaining material in STM does not seriously affect iconic memory. Although there was a substantial difference between the E1 condition and the E2 and E3 conditions at 0 msec, two observations suggest that this difference does not reflect a decrement in iconic memory. First, recall levels were equivalent across conditions for the remaining delays. Second, there was a slight rise in performance from 0 msec to 100 msec in Condition E1 and a decline in performance from 0 msec to 100 msec in Conditions E2 and E3. Clearly, the reason for the difference at 0-msec delay could not have been a reduction in the capacity of iconic memory. The data of Experiment 1 corroborate and extend a previous observation by Turvey (1966) that rehearsing a sequence of items in STM does not reduce the level of recall of items from the iconic store.

EXPERIMENT 2

In the second experiment a more stringent test of the hypothesis that iconic memory is independent of CPC was sought by requiring S to perform a classification task concurrent with iconic storage and before the readout from it occurred. Classification of items involves a number of mental operations and, therefore, imposes a demand on the CPC of S (see Posner, 1966). If iconic memory requires a certain portion of the limited CPC, and a classification task also requires a certain portion of CPC for its performance, then iconic memory and/or the classification task should suffer a decrement when both demands are made on S concurrently. Poorer retrieval would be expected from iconic memory, and/or an increase in error rate and reaction time (RT) would be expected for the classification task.

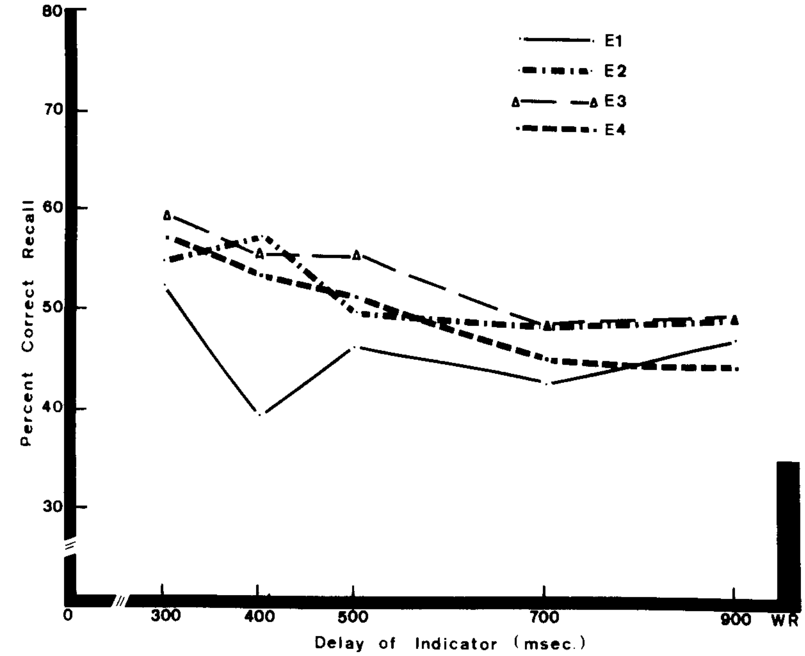

Fig. 2. Percent correct recall as a function of delay of indicator and condition for Experiment 2.

Method

Subjects. The Ss were the same as in Experiment 1.

Materials and apparatus. A stereotape was made. On one tape (Channel 1) sets of 12 letters were recorded. The letters were: a, e, i, o, u, f, h, l, p, r, s, x. The consonants used were selected to minimize acoustic confusion. Each letter was recorded so that the duration of its presentation would not exceed 180 msec. This was achieved by having a speech expert record repetitions of a particular letter, making the sound as brief as possible. The briefest and still clearly recognizable letter sound was selected. Those letters that exceeded the 180-msec duration were cut by trial and error into segments and replaced to produce a clear intelligible 180-msec sound.

On a second tape (Channel 2) a tone was recorded that served, via a series of Hunter timers, to trigger the tachistoscope. The contacts on the tachistoscope shutter were connected to an audiogenerator that fed back into Channel 1 on the tape recorder. This gave one tone that started the display sequence and a second tone that indicated the latency from the initial tone to the opening of the shutter of the tachistoscope. The second tone thus gave the place where the letter on Channel 1 was to be placed, making it possible to precisely coordinate the presentation of the visual display and the auditory stimulus. The final tape had six sets of 12 letters. The order of the letters in a set was random and the letters were presented to S via earphones.

A Hunter digital counter/timer, Model 1520, was connected to the contacts on the shutter of the tachistoscope and to two telegraph keys. The opening of the shutter started the timing device, which was terminated by S depressing one of the keys. Each key was connected to a light so that E could determine which key had been pressed.

The 3 by 5 letter matrices of Experiment 1 were used. Throughout the experiment the duration of the tachistoscopic display of a matrix was 180 msec.

Procedure. Each S served in seven sessions on 7 successive days. On Day 1 Ss were given instruction and practice in the classification task and whole report data were collected. One of the two telegraph keys was designated as the "vowel" key and the other as the "consonant" key. One hundred trials were given in which S depressed the appropriate key to classify the letters presented in the acoustic mode. Each S was instructed to perform the classification task as quickly as possible, yet still retain accuracy. After a 15-min rest, 60 whole report trials of the Sperling task were conducted, the first 10 serving as practice trials.

On Day 2 Ss were given 60 trials in which they were required to classify the aurally presented letter and respond to the visual display. The auditory letter and the visual display occurred concurrently. S had to press the appropriate key classifying the letter as vowel or consonant and then, at one of five delay intervals, a tone indicator would occur specifying recall of a particular row of letters in the matrix display. The delay of indicator intervals were 300, 400, 500, 700, and 900 msec. These delay intervals began on termination of the matrix display which was of 180-msec duration.

Following a brief rest, Ss were given 60 trials comprised of the same events, except that S did not have to classify the auditory letter.

On Day 3 data were collected on the reaction time (RT) of S to classify the aurally presented letters when they were presented alone and when they were presented concurrently with the visual display. Two Ss received 60 trials of classifying the aurally presented letters when they were presented alone (RTA), followed by 60 trials of classifying the letters when they were accompanied by the visual display (RT + D). In this latter case S did not have to report material from the display. The other two Ss were given the same conditions in the reverse order. Each series of 60 trials was preceded by 10 practice trials.

Four experimental conditions were partially counterbalanced across Days 4-7 such that no condition was given to more than one S on any one day. Each condition involved 100 trials with 20 sec elapsing between trials. In each condition the 100 trials were preceded by 10 to 15 practice trials. The conditions presented on Days 4-7 are described below by reference to the sequence of events comprising a trial. Condition E1: (1) E said "ready;"

Table 1
RT Means, Standard Deviation, and Errors for Individuals and Group for E1, RT + D, and RTA for Experiment 2

S	Condition	M	SD	Proportion Error
1	E1	419	75.62	.10
2	E1	372	96.52	.19
3	E1	446	110.39	.09
4	E1	450	72.74	.10
Group	E1	423	94.71	.12
1	RT + D	397	83.05	.08
2	RT + D	395	96.86	.14
3	RT + D	387	112.43	.14
4	RT + D	468	64.68	.04
Group	RT + D	413	96.60	.10
1	RTA	408	79.70	.12
2	RTA	440	85.28	.08
3	RTA	449	94.56	.16
4	RTA	456	96.78	.06
Group	RTA	438	74.03	.11

Table 2
RT Means, Standard Deviation, and Errors for Individuals and Group for E1, RT + D, and RTA for Experiment 3

S	Condition	M	SD	Proportion Error
1	E1	388	73.9	.08
2	E1	420	89.18	.10
3	E1	457	85.4	.12
4	E1	436	100.8	.17
Group	E1	425	91.0	.12
1	RT + D	475	65.6	.17
2	RT + D	451	79.1	.07
3	RT + D	462	74.4	.15
4	RT + D	400	93.7	.15
Group	RT + D	421	85.1	.13
1	RTA	381	73.4	.10
2	RTA	449	59.7	.05
3	RTA	455	35.2	.07
4	RTA	432	95.0	.17
Group	RTA	430	80.4	.10

(2) a visual matrix and an auditory letter were delivered simultaneously to S; (3) as rapidly as possible S pressed an RT key to classify the auditory letter; (4) a tone indicator occurred at one of the five delays; (5) S wrote down on the response sheet the appropriate row of letters. Condition E2: The same as E1 except that Event 3 was deleted, i.e., S did not have to respond to the auditory letter. Condition E3: The same as E1 except that S did not have to perform Event 3 but did have to report after Event 5 which class of letter, vowel, or consonant had been presented auditorily. This condition required that S store the auditory information while performing the iconic task. Condition E4: This was the principal control condition. After Event 1 S was presented the letter matrix alone, followed at one of the five delays by a tone indicator. This condition, therefore, did not involve S performing a task concurrently with the iconic memory task.

Results and Discussion

Table 1 gives the mean RTs, standard deviations, and errors for the RTA, RT + D, and E1 conditions. Table 1 reveals that the time taken to classify the auditory letter in Condition E1 was sufficiently short so that S could complete the task before the 300-msec tone indicator occurred. The 300-msec interval was the shortest delay used in Experiment 2. While inspecting Table 1, it should be noted that the clock measuring the RTs started with the opening of the shutter and, therefore, the RTs include the exposure duration for the 3 by 5 matrix of 180 msec. The tone delay was measured from the termination of the matrix display. Observation of Table 1 indicates that the error rate and RT for classifying the auditory input were approximately the same for all three conditions.

Figure 2 shows the percent recall at each delay for Conditions E1, E2, E3, and E4, plus the whole report baseline derived from data collected on Day 1. Even though one S (S 3) found experiment demands too great for adequate performance, particularly in Condition E1, his data were included in the Treatment (Conditions) by Treatment (Delay) by Ss analysis of variance. Means were calculated for each tone-delay combination for the analysis. The analysis revealed that the conditions effect was insignificant [$F(3,9) = 3.47$, $p > .05$], despite the apparently poorer E1 performance reflected in Fig. 2. The main effect of delay was significant [$F(4,12) = 15.79$, $p < .001$], but the Conditions by Delay interaction was not.

Only three errors were registered across all Ss in the recall of the class of the auditory letter in Condition E3.

Given that the conditions effect fell short of the conventional levels of significance and given that the RT for classifying the auditory letter did not vary across conditions, we may take the data of Experiment 2 as support for the hypothesis that iconic memory is relatively independent of CPC. However, the tendency for E1 performance to be at a lower level than the other conditions, as shown in Fig. 2, and the somewhat erratic E1 function with recovery at the 900-msec delay suggests that the null hypothesis should be accepted with some reservation. Replication of the results was required.

EXPERIMENT 3

Experiment 3 differed in two important respects from Experiments 1 and 2. First, the criterion for selection from iconic memory used in Experiment 3 was shape, as opposed to the selection criterion of location, which had been used in the previous two experiments. An experiment by Turvey and Kravetz (1970) had shown that shape was an efficient selection criterion for material in iconic memory. Second, tone and delay were fully counterbalanced across trials in Experiment 3 so that each tone occurred the same number of times at each delay. The use of shape as the selection criterion had two purposes: to test whether iconic memory was unaffected by other, concurrent demands imposed upon the information-processing system when the criterion for recall from iconic memory was something other than location and to eliminate a particular S bias which had emerged under the task demands of Experiment 2—a bias toward the middle row of the matrix.

Method

Subjects. The Ss were the same Ss who had performed in Experiments 1 and 2 except for one S who had difficulty with the experimental task in Experiment 2 and was discarded on completion of that experiment. The discarded S was replaced by a new S.

Materials and apparatus. The materials and apparatus were the same as had been used in Experiment 2 with the following exceptions. Forty slides were constructed with three rows of four letters. Each of three letters, R, O, and Z, appeared four times in random order on a slide. This set of slides replaced the 3 by 5 letter matrices used in Experiments 1 and 2. The new slides displayed a visual angle of 2 deg 24 min vertical x 3 deg 20 min horizontal at the viewing distance of 7.5 ft. A new randomization of the letter sets on the tape of Experiment 2 was made and the intertrial interval was reduced to 12 sec.

Procedure. The new S was given 5 h of training extended over 4 days, approximating the training procedure of Experiment 2. On Day 1 of the

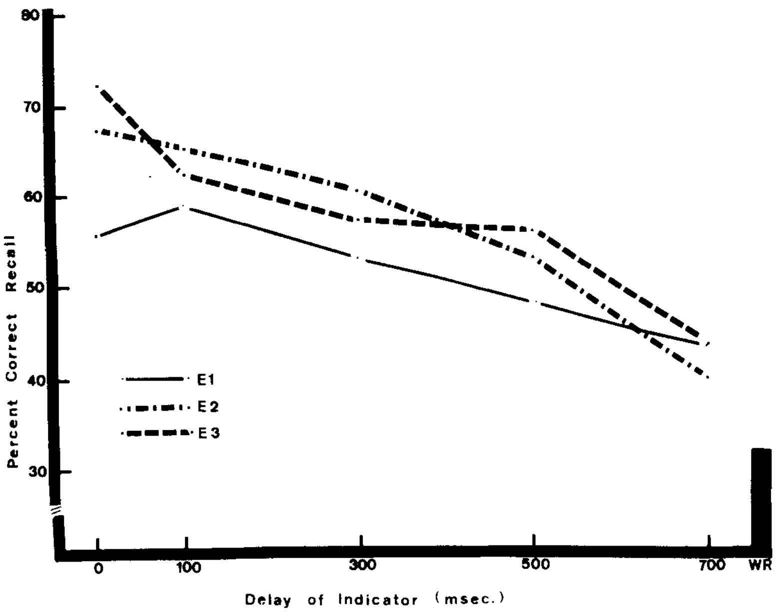

Fig. 3. Percent correct recall as a function of delay of indicator and condition for Experiment 3..

Experiment 3 program, each S was given 10 practice trials on the classification task, followed by 60 RTA trials and/or 60 RT + D trials, two Ss receiving each order. After a brief rest, each S was then given 60 trials on the Sperling task with the new matrices and the new selection criterion. The tone indicators were now associated with letter shape. The high tone specified recall of the Os, the middle tone recall of the Rs, and the low tone recall of the Zs.

On Day 2 each S received 60 trials of partial report by shape followed by 60 whole report trials. Throughout Experiment 3 the tone indicator delays were 300, 400, 600, and 1,000 msec.

Four experimental conditions identical to Conditions E1, E2, E3, and E4 of Experiment 2 were conducted across Days 3-6 of the experimental sequence. Each condition was given once on each of Experimental Days 3-6. There were 120 trials in each condition, preceded by 10 practice trials. Sessions followed each other by no less than 3 h and by no more than 24 h.

Results and Discussion

Table 2 gives the mean RTs for the RTA and RT + D conditions obtained on Day 1 and the mean RT for the E1 condition obtained from Days 3-6. Although there were only 2 days on which S was required to perform the RT task, on Day 1 and on whichever day S happened to receive Condition E1, the RTA and RT + D data were always collected before the E1 data. However, comparison of Table 1 and Table 2 indicates, as had been expected, that there was little change in RT performance beyond the initial training trials of Experiment 2. A direct comparison across experiments of the performances on the RTA and RT + D tasks of the three Ss who served in both Experiment 2 and Experiment 3 (Ss 1, 2, and 4) revealed no significant change in RT performance.

Inspection of Table 2 indicates that the mean RTs did not vary across Conditions E1, RTA, and RT + D in any fashion which would suggest that RT performance in the E1 condition was significantly imparied. As in Experiment 2, the RT measures reported in Table 2 include the display duration of 180 msec.

Figure 3 shows the percent recalled at each delay interval for Conditions E1, E2, E3, and E4, plus the whole report baseline. A Treatment (Conditions) by Treatment (Delay) by Ss analysis of variance was performed on the mean recall for each S calculated for each tone-delay combination. The main effect of conditions was insignificant ($F < 1$), as was the Conditions by Delay interaction ($F < 1$). The main effect of delay also fell short of significance [$F(3,9) = 3.71$, $.05, p < .10$].

The general superiority of partial report by shape over whole report, obtained in Experiment 3, corroborates Turvey and Kravetz (1970) and indicates that items can be efficiently selected from iconic memory on the basis of shape characteristics. However, unlike the Turvey and Kravetz experiment, Experiment 3 did not reveal a significant effect of delay. It is, of course, possible that if shorter delays had been used, as well as the delays in the range of 300-1,000 msec, a significant effect of indicator delay would have been observed. It is notable, however, that the partial report performances of Conditions E1, E2, E3, and E4 are still substantially higher than the whole report performance at the longest delay of 1,000 msec. The main differences that immediately come to mind between the present experiment and the Turvey and Kravetz experiment are that the duration of the display is longer in the present experiment, 180 msec compared to 100 msec, and that the Ss had more practice with the Sperling task in the present experiment. It is perhaps important to note that an experiment by Clark (1969) similarly failed to observe a decline in report as a function of delay of indicator. In Clark's experiment the selection criterion was color, suggesting, perhaps, that one might expect to find, in as yet unspecifiable circumstances, instances when the temporal function of report by category (e.g., color, shape) differs from that of report by location (see Dick, 1969).

GENERAL DISCUSSION

The results of the three experiments offer strong support for the suggestion that iconic memory is relatively independent of the central processing system. In the present experiments, demands on CPC in the form of requiring S to perform either an STM task or a classification task concurrently with performance of the iconic memory task did not produce a significant decrement in report from iconic memory. Furthermore, if iconic memory is assumed to require a substantial portion of CPC, the subsidiary tasks should have suffered. The data, however, indicated no detrimental effect of the iconic memory task on the concurrently performed classification task. However, the caveat is respected that more complex tasks performed concurrently with iconic memory could adversely affect accuracy of report from and/or persistence of iconic memory. At best, one can conclude from the present data that iconic memory does not require a substantial portion of CPC for its maintenance.

Recently Posner and his associates (see Posner, in press) have investigated visual memory using an RT method. In this method a letter presented visually for .5 sec was followed after varying delays by a second letter. The S had to press one key if the delayed letter was the same physically or in name and another key if the letter was different. Matches that were physically the same were consistently faster than those that were the same in name. The superiority of the physical match over the name match rapidly decreased, however, with increase in delay of the second letter. At longer delays of the second letter, physically similar letters were matched, apparently, on the basis of a name code rather than on the basis of a visual code. Is this visual code investigated by Posner the same as iconic memory? Posner suggests that it is not. As Posner indicates, the visual code for a letter detected by the RT method is not influenced by variables such as intensity or duration of the letter display. On the other hand, iconic memory is influenced by such variables (Neisser, 1967). Furthermore, the visual code or visual memory investigated by Posner is dependent on CPC for its maintenance (Posner, in press). The present experiment suggests that iconic memory is not dependent on CPC. At the present time, therefore, it appears that iconic memory and the visual memory identified by Posner reflect different representations of visual information.

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(Accepted for publication May 28, 1970.)