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Presentation Rate and the Representation of Briefly Glimpsed Pictures in Memory

Helene Intraub
Massachusetts Institute of Technology

Four experiments on memory for briefly presented complex pictures showed the following: (a) Pictures shown in a sequence for 110 msec each with a blank 5,890-msec interstimulus interval (ISI) were later recognized almost as well as pictures shown for 6 sec each with no ISI; (b) when the ISI was deleted, recognition memory for the briefly presented pictures dropped almost to chance; (c) however, filling a 5-sec ISI with a to-be-ignored picture that was the same on all trials had little or no effect on memory for the briefly presented pictures; (d) when the time between 110-msec pictures was decreased from 4,890 to 1,390, 620, 385, or 0 msec, the ability to detect that they were mirror reversed in the recognition test decreased more rapidly than did recognition accuracy. Evidently, incidental visuospatial properties of a picture can be encoded for at least 1 sec after a brief presentation unless another to-be-remembered picture is presented during that time.

A compelling feature of recognition memory for pictures is that thousands of pictures, each viewed for only a few seconds, are retained extremely well (e.g., Standing, 1973). This excellent level of performance drops dramatically, however, when the duration of each picture in a continuous sequence is reduced from 2 sec to 125 msec (Potter & Levy, 1969). The purpose of the present research was to gain insight into pictorial encoding by examining the reasons for this decline. Three issues are addressed.

The first issue concerns the relative importance of stimulus duration and stimulus off time (i.e., the time between stimuli) in pictorial encoding. Clearly, recognition memory suffers when the duration per picture is decreased (Lutz & Scheirer, 1974; Shaffer & Shiffrin, 1972; Tversky & Sherman, 1975; Weaver, 1974; Weaver & Stanny, 1978). One suggestion regarding the effect of stimulus duration is that it places a limit on the number of eye fixations that can be made on a picture, thereby terminating the transfer of visual details to long-term memory (Loftus, 1972). The effect that stimulus off time has on

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Requests for reprints should be sent to Helene Intraub, who is now at the Department of Psychology, Bucknell University, Lewisburg, Pennsylvania 17837.

recognition memory, however, has not been as clearly established. In one study, no effect of stimulus off time was obtained (Shaffer & Shiffrin, 1972). In others, an effect was obtained but varied markedly in magnitude from one study to the next (Intraub, 1979; Lutz & Scheirer, 1974; Tversky & Sherman, 1975: Weaver, 1974; Weaver & Stanny, 1978). The temporal conditions and testing procedures used in those experiments, however, also varied markedly. To control these factors, standard testing procedures and a wide range of temporal conditions were used in Experiments 1 and 2 to examine the relative contributions of stimulus duration and stimulus off time to memory for pictures.

The second issue that was examined concerns the stimulus conditions that cause a disruption of encoding when the rate of presentation is increased. It has been suggested that the processing of a picture is terminated by the occurrence of a substantial change in the visual field (Potter & Levy, 1969). Another suggestion is that backward masking plays a major role in disrupting memory for successively presented pictures at rates such as those employed in Potter and Levy's most rapid conditions (e.g., Rosenblood & Poulton, 1975). The effect that the immediate presentation of another picture has on encoding of a briefly presented picture was tested by presenting sequences in which the interstimulus interval (ISI) contained either a homogeneous field or a picture that repeated throughout the sequence. Experiments 1, 3, and 4 examined memory for the briefly presented pictures under both conditions.

The third issue addressed concerns the nature of the processes occurring during stimulus off time. An experiment was conducted to determine if decreases in the ISI impair memory because fewer pictures can be processed as presentation rate is increased (e.g., a fixed number per unit time) or because, in addition, less information about each picture is stored. This issue is discussed in Experiment 2.

Experiment 1

Stimulus duration and total study time (stimulus duration plus stimulus off time) were varied independently to determine the effect that each has on retention of pictures. To determine if the appearance of a meaningful visual event interferes with processing of a briefly presented picture, pictures were presented with ISIs filled by presentation of either a homogeneous field or a complex picture that repeated throughout the sequence. If pictures are processed only until the next meaningful input, then recognition accuracy should decrease dramatically when the ISI contains a picture rather than a blank field. In principle, recognition memory for pictures in the picture-filled-ISI condition should be identical to that obtained for pictures presented for the same brief duration but with no ISI (continuous presentation).

Method

Subjects. Subjects were 80 undergraduate volunteers from Brandeis University reporting normal or normal-corrected vision.

Stimuli. One-hundred-fifty stimuli were chosen from a set of 252 color magazine photographs used by Intraub (1979). (Stimuli for Experiments 1–4 were selected from this set.) The cutout pictures included 1–3 main objects and were photographed in the center of a homogeneous medium-gray background. Kodak KPA-135 color 35-mm film and Kodachrome II, Type A 8-mm movie film were used to minimize differences in color balance between slides and movies.

Apparatus. Stimuli were presented using a Gerbrands Model G1170 two-channel projection tachistoscope driven by two Hunter Model 131c interval timers, except in the case of the most rapid presentation sequence for which a Bolex 8-mm standard speed (18 frames per sec projector) was used. In both cases, stimuli were projected on a screen approximately 1.2 m from the subjects; the field was approximately 14° × 14°.

Design and procedure. The 150 pictures were presented in four different conditions. There were 20 subjects in each condition, run in groups of 3 or 4. In the 6-sec continuous condition, the pictures were presented for 6 sec each in a continuous sequence. In the blank-ISI condition, the pictures were presented for 110 msec each, with a 5,890 msec ISI during which a homogeneous medium-gray field was presented. The picture-filled-ISI condition was identical to the blank-ISI condition, except that a picture was projected during the ISI.

Two different ISI pictures were employed; each was presented to half of the subjects in the filled-ISI condition. In the 110-msec continuous condition, the pictures were presented for 110 msec each in a continuous sequence.

All subjects were instructed to attend to each picture in the inspection sequence and were informed that a recognition test would follow. Subjects in the picture-filled-ISI condition were familiarized with their ISI picture at the beginning of the session. They were instructed to attend *only* to the briefly presented stimulus pictures during presentation. Prior to the experiment, all subjects were presented with a sample sequence containing 20 pictures to familiarize them with the viewing conditions.

There were two random orders of the 150-picture inspection sequence; each was used for half of the subjects in each condition. Approximately 2 min following presentation, a serial yes–no recognition test was administered. The test includes 30 targets (selected equally often from the first and second halves of the sequence) randomly mixed with 30 distractors (pictures not previously seen). Distractors that did not bear a close resemblance to any of the stimuli were chosen. Pictures in the recognition test were presented for 3 sec each. Subjects were instructed to adopt a strict criterion and to write *yes* if they recognized a picture and *no* otherwise. Two different sets of targets were used, and each set was presented to half of the subjects in each condition, to serve as an internal replication.

Results and Discussion

The mean and median proportion of correct *yes* responses for each condition are presented in Table 1. Also in Table 1 are the proportion of *false yes* responses (incorrect *yes* responses) and the proportion of pictures recognized, corrected for guessing.[1] Consistent with research showing that both stimulus duration and ISI affect memory for pictures, recognition accuracy was highest in the 6-sec continuous condition, decreased in the blank-ISI condition, $t(57) = 10.56$, $p < .002$, and diminished further in the 110-msec continuous condition, $t(57) = 9.38$, $p < .002$ (planned comparisons, two-tailed).[2] The change in total study time, however, had a significantly greater effect on performance than did the change in exposure duration, $t(57) = 2.26$, $p < .05$ (planned comparisons, two-tailed). If transfer of visual details to long-term memory were dependent on the number of eye fixations made on a picture (e.g., Loftus, 1972), then recognition memory should have declined precipitously when duration alone was cut to 110 msec, reducing the number of fixations per picture from about 18 to 1.[3] However, when duration was reduced from 6 sec to 110 msec with total study time held constant, a decrease in recognition accuracy of only 17% was obtained. On the other hand, when stimulus duration was held constant and the ISI was deleted, a relatively large reduction in recognition accuracy (a decrease of 54%) was obtained.

Table 1
Mean and Median Proportions of Correct Yes *Responses and Mean Proportion of* False Yes *Responses and Corrected* Yes *Responses in Each Condition*

Stimulus duration[a]	ISI[a]	M	Mdn	FY	M_c
6,000	0	.94	.97	.08	.94
110	5,890 (blank)	.80	.83	.11	.77
110	5,890 (filled)	.77	.83	.12	.73
110	0	.40	.37	.27	.21

Note. ISI = Interstimulus interval; FY = Mean proportion of *false yes* responses; M_c = Mean corrected proportion of pictures recognized.
[a] Data are in msec.

Presentation of a to-be-remembered repeating picture during the ISI did not reduce recognition memory of the briefly glimpsed pictures to the same low level obtained in the 110-msec continuous condition. In fact, recognition memory performance obtained in the picture-filled-ISI condition did not differ significantly from that obtained in the blank-ISI condition, $t(38) = .43$. This suggests that backward masking cannot account for the low level of recognition accuracy obtained following rapid continuous presentation. Consistent

[1] The formula used to correct for guessing was $Y_c = (TY - FY)/(1 - FY)$ in which Y_c is the corrected proportion of *yes* responses, TY is the proportion of *yes* responses to old pictures, and FY is the proportion of *yes* responses to distractors.

[2] All analyses were conducted on arcsine transformed proportions in this and the following experiments.

[3] Yarbus (1967) and others report about three fixations per second on a picture.

with this observation, Potter (1976) demonstrated that when briefly exposed pictures were interspersed with presentation of a colorful visual noise mask, recognition memory far surpassed that obtained when the same pictures were presented in a continuous sequence. Evidently, processing of a picture with duration of at least 110 msec can continue despite the onset of a meaningless visual noise mask or a meaningful picture that repeats throughout the sequence.

Perhaps processing of a picture is more likely to continue following its offset if the visual scene that replaces it does not itself require the same level of attention. A blank field, a to-be-ignored repeating picture, or a repeating visual noise mask (as in Potter's, 1976, experiment) would not be expected to elicit the same depth of processing as the novel pictures that the subjects were instructed to remember. That is, in the picture-filled-ISI condition, where memory for the briefly presented pictures was good, successively presented pictures did not all require like processing as they did in the 110-msec continuous condition. Further support for the processing demand requirement is provided by recent research in which a new to-be-ignored picture was presented during the ISI each time. Although recognition memory performance for the briefly presented stimuli was slightly lower under this condition than when a repeating picture was presented during the ISI each time, recognition memory did not approach the low level obtained following rapid continuous presentation. This level was only reached when attention instructions were altered, placing greater emphasis on memory for the 1.5-sec ISI pictures as opposed to memory for the briefly presented stimuli (Intraub, Note 1). This suggests that the necessity for like processing of successive pictures may be one source of the disruption of encoding that occurs as rate is increased. The way in which this disruption is manifested was examined in Experiment 2.

Experiment 2

When stimulus duration is held constant and the time between pictures is reduced, recognition memory suffers. This deficit in memory may be caused in one of two general ways. One possibility is that encoding is an all-or-nothing process that requires a fixed amount of time to be completed for a given picture. As the time between pictures is decreased, encoding can be completed for fewer pictures. For example, perhaps only those pictures that can be encoded before onset of the next to-be-remembered picture will be retained or perhaps subjects can voluntarily attend to a picture until encoding is complete, missing subsequent pictures presented during that time. In either case, although fewer pictures will be retained as the ISI is diminished, those few pictures that are recognized following a rapid presentation will be remembered in as much detail as pictures that are presented following a slower presentation. The other possibility is that rather than being an all-or-nothing process, encoding is a continuous process. As the time between pictures is reduced, fewer pictorial details can be stored. Recognition memory suffers because fewer pictures will be stored in enough detail to pass a recognition threshold during testing. According to this view, as the time between pictures is reduced, not only will fewer pictures be recognized but they will be remembered in less detail than pictures that are presented at a slower rate.

A traditional recognition test employing dissimilar distractors cannot distinguish between these hypotheses because a minimal amount of semantic or visual information might be sufficient for a recognition response. To determine if less is remembered about each picture when presentation rate is increased, a recognition test with two levels of difficulty was used in Experiment 2. Half of the targets in the recognition test were mirror reversals of pictures from the inspection sequence. After making a *yes* response, subjects were required to indicate whether the picture was normal or reversed. Ability to report mirror reversal was selected because in addition to providing a more stringent test of visual memory, reversing a picture alters neither spatial relations within the picture nor the picture's meaning. If encoding is an all-or-nothing process, the ability to detect mirror reversal of correctly recognized pictures should remain constant, regardless of the duration of stimulus off time and the proportion of remembered pictures. If encoding is a continuous process that allows for a more detailed and complete representation in memory as more time is allowed, detection of reversal among remembered pictures should diminish when stimulus off time is reduced.

Method

Subjects. Subjects were 60 undergraduates from Brandeis University reporting normal or normal-corrected vision.

Stimuli. The stimuli were 16 pictures exhibiting asymmetry about the vertical axis. There were no alphanumeric characters that would indicate normal orientation.

Apparatus. Subjects were seated in an anechoic chamber approximately 60 cm from a rear projection screen. A three-channel projection tachistoscope driven by four Hunter timers was used for sequences in which the ISI was 385 msec and longer. A filmed (8-mm) sequence was used in the condition requiring continuous presentation. During the recognition test, an impulse to the stimulus shutter triggered a Heath digital reaction timer. Vocal responses into a microphone stopped the timer. In all conditions, the pictures were contained in a 12° × 12° field.

Procedure. There were six conditions of presentation with 10 subjects run individually in each. In the 5-sec continuous condition, pictures were presented for 5 sec each with no ISI. In the remaining five conditions, stimulus duration per picture was always 110 msec with ISIs of 4,890, 1,390, 620, 385, or 0 msec. A homogeneous medium-gray field was projected during the ISI. Two pictures from the general picture set were included at the beginning and two at the end of each sequence as buffers for primacy and recency effects. Recognition of those four pictures was not tested. The same order of presentation was used in all conditions. Subjects were instructed to attend to each picture and to try to remember as many as possible because a recognition test would follow the inspection sequence. Prior to viewing the inspection sequence, all subjects were presented with an eight-picture sample sequence to familiarize them with the viewing conditions.

Table 2
Proportion of Pictures Recognized (Corrected), Proportion of False Yes *Responses, the Conditional Probability of Reversal Detection (With and Without Correction), and the Proportion of Normal Pictures Called Reversed in Each Condition*

Stimulus duration[a]	ISI[a]	M_c	*FY*	CPRD	$CPRD_c$	*FR*
5,000	0	.96	.02	.82	.81	.03
110	4,890	.84	.01	.58	.56	.17
110	1,390	.84	.03	.61	.60	.06
110	620	.61	.09	.38	.32	.17
110	385	.48	.13	.33	.26	.10
110	0	.20	.08	.17	.08	.09

Note. ISI = interstimulus interval; M_c = mean corrected proportion of pictures recognized; *FY* = *false yes* responses; CPRD = conditional probability of reversal detection; $CPRD_c$ = corrected conditional probability of reversal detection; *FR* = false reversed responses.
[a] Data are in msec.

The recognition test consisted of all 16 stimuli randomly mixed with 16 distractors that were also asymmetrical about the vertical. The stimuli were divided into two groups of 8. Each group was mirror reversed for half of the subjects in each condition.

Recognition instructions. Only *after* presentation of the inspection sequence were subjects informed of the reversal detection task. They were instructed to respond *yes* if they recognized a picture (regardless of left–right orientation) and *no* if not, as quickly as possible; vocal reaction time was recorded. Subjects were told to consider left–right orientation only *after* making a *yes* response, responding *reversed* if they thought the target was mirror reversed and responding *normal* otherwise. Subjects were allowed as much time as necessary to make this decision. (The picture remained on the screen during this time.) They were encouraged to use strict criteria for both decisions. At debriefing it was learned that none of the subjects had anticipated anything other than a traditional recognition test.

Results

Recognition accuracy (yes *responses*). The effect of total study time on recognition memory for pictures was similar to that observed in Experiment 1. The corrected proportion of pictures recognized and the proportion of *false yes* responses for each condition are shown in Table 2. A small significant decrease in recognition

Table 3
Mean Response Latencies and Standard Deviation for All Targets, Normal Targets, and Reversed Targets in Each Condition

Stimulus duration[a]	ISI[a]	RT_{all} *M*	RT_{all} *SD*	RT_{norm} *M*	RT_{norm} *SD*	RT_{rev} *M*	RT_{rev} *SD*
5,000	0	1,270	273	1,222	276	1,315	288
110	4,890	1,162	234	1,108	208	1,221	299
110	1,390	1,171	229	1,120	210	1,242	292
110	620	1,142	332	1,040	350	1,003	287
110	385	1,141	190	1,101	197	1,173	250
110	0	1,360	249	1,377	376	1,405	231

Note. ISI = interstimulus interval; RT_{all} = reaction time to all targets; RT_{norm} = reaction time to normal targets; RT_{rev} = reaction time to reversed targets.
[a] Data are in msec.

memory was obtained when duration was reduced from 5,000 to 110 msec with total study time held constant, $t(18) = 2.56$, $p < .025$ (two-tailed). A more pronounced drop in recognition was obtained when the ISI was diminished, $F(4, 45) = 24.0$, $MS_e = 14,378.6$, $p < .001$. An analysis of variance conducted on the proportion of *yes* responses and the proportion of *false yes* responses for each subject revealed that overall, when duration was 110 msec, recognition memory was better than chance, $F(1, 45) = 450.7$, $MS_e = 2,037,620.0$, $p < .001$. At all rates every subject made more hits than false alarms.

Reversing a picture during the recognition test did not significantly affect the subject's ability to tell that the picture had been seen before (Wilcoxon matched-pairs tests). Overall, an average of 5.7 out of 8 normally oriented pictures and 5.5 out of 8 reversed pictures were recognized. Mean response latencies to correct *yes* decisions are shown in Table 3. No difference in response latency was obtained among the five 110-msec conditions, $F(4, 45) = 1.37$. Also shown in Table 3 is the mean response latency to normal and reversed pictures in each condition. The overall mean latency to *yes* responses was 1,153 msec for normal pictures and 1,234 msec for reversed pictures. This tendency for longer response times to reversed pictures did not reach significance, $F(1, 45) = 3.81$, $MS_e = 243,422.0$, $p < .06$, nor was there a significant interaction with condition ($F < 1$). When only those pictures correctly identified as being reversed or normal were included in the analysis, there was still not a significant difference in latency.

Reversal detection. Contrary to the all-or-nothing hypothesis, ability to detect that a correctly recognized picture was mirror reversed diminished not only when stimulus duration was reduced but when stimulus duration was held constant and ISI was reduced. When a reversed picture was recognized, the probability that the subject detected its reversed orientation is shown in Table 2 for each condition. When stimulus duration was decreased from 5,000 to 110 msec (with total study time held constant), the conditional probability of reversal detection decreased by .24, $t(18) = 2.77$, $p < .025$ (two-tailed). Recall that the decrease in recognition of the pictures themselves, regardless of orientation, was only .12. At stimulus duration of 110 msec, as the ISI was reduced, the conditional probability of reversal detection dropped still further, $F(4, 45) = 7.26$, $MS_e = 1,271.33$, $p < .001$.

Rather than reflecting a reduction in the ability to detect reversal, the decline in conditional probability could be an artifact of a guessing bias. An artifactual decline in the probability of reversal detection would be obtained if subjects (a) made more recognition guesses as rate was increased (resulting in more lucky hits) and (b) tended to call these guesses normal due to the instruction bias. To test this, a guessing correction that takes into account the proportion of false alarms that are called *normal* and those that are called *reversed* was applied to the probabilities.[4] The corrected scores, shown in Table 2, do not support the guessing bias hypothesis. If anything, the corrected scores show a more pronounced decrease in the conditional probability than do the raw scores.

The proportion of normal stimuli falsely called *reversed* (*false reversed* responses) in each condition is shown in Table 2. Although reversal detection was better than chance overall, $F(1, 45) = 30.66$, $MS_e = 20{,}649.69$, $p < .001$, this was not the case in all the conditions. Whereas *all* subjects made more *correct yes* responses than *false yes* responses, the number of subjects (out of 10) with more *correct reversed* than *false reversed* responses was 9, 10, 8, 6, and 5, in the slow to fast conditions, respectively. At a stimulus duration of 110 msec, reversal judgments were better than chance only in the ISI–4,890-msec and ISI–1390-msec conditions ($p < .04$, sign test, two-tailed).

Discussion

The results show that rather than being an all-or-nothing process, pictorial encoding involves in part the establishment of an increasingly detailed memory representation of a picture over time. Although subjects could successfully recognize some pictures following *all* of the presentation rates employed, the ability to detect which of these pictures were reversed was lost when the time between to-be-remembered pictures was reduced. This occurred even though stimulus duration was held constant at only 110 msec, preventing the subject from scanning the picture while encoding was taking place.

Since verbal or numerical configurations did not appear on any of the stimuli, it is unlikely that the left–right orientation of any of these pictures was relevant to its meaning. Even so, subjects frequently retained this semantically "unimportant" information when the total study time was 1,500 msec or greater. Subjects reported to their own surprise that certain pictures simply *looked* backwards. Whether or not the reversal was detected, reversing a stimulus did not interfere with recognition (a finding also reported by Standing, Conezio, & Haber, 1970). This casts doubt on a description of recognition memory as a templatelike matching process. Although there was some suggestion that response latencies were longer to reversed than to normal targets, this effect was not as strong as might be expected if subjects were "mentally rotating" the target to match a memory image. Response time, however, was taken to the yes–no decision and not to the normal–reversed decision. A precise image match, therefore, may not be necessary for general recognition, although it might be used in reversal detection. What the results do indicate is that when stimulus duration or stimulus off time is decreased, less complete visuospatial information about a picture is retained.

The results also stress the importance of test sensitivity in measuring memory. For example, in the present experiment, the disparity in retention between the 5-sec continuous and the ISI–4,890-msec conditions was considerably more pronounced when reversal detection as opposed to recognition memory was tested. When a traditional serial recognition test is used to measure memory, it cannot be assumed that recognition implies retention of even a global visuospatial characteristic such as left–right orientation. Indeed, the observation that reversal neither affected recognition of a picture nor significantly inflated

[4] The conditional probability of reversal detection is obtained by TRR/TYR, where TYR is the proportion of *yes* responses to reversed pictures, and TRR is the proportion of *reversed* responses to reversed pictures. To correct the conditional probability for the guessing bias described in the text, using the formula in Footnote 1, TYR was corrected using the proportion of *yes* responses to distractors (FY) and TRR was corrected using the proportion of *reversed* responses to distractors (FYR).

reaction time suggests that recognition can be based on conceptual characteristics and limited visual information about a picture. (Note that covert naming is unlikely at the fastest rates employed.)

The issue of test sensitivity may also apply to the interpretation of the Shaffer and Shiffrin (1972) study. In that experiment when the ISI was varied between 1 and 4 sec, no effect of ISI on recognition accuracy for pictures was obtained. Weaver (1974) and Tversky and Sherman (1975), on the other hand, obtained an effect of ISI when similar stimulus durations and ISIs were used. In the latter experiments, however, distractors that were visually similar to the targets were employed, whereas in the Shaffer and Shiffrin experiment (as in the experiments presented in this article) dissimilar distractors were employed. In the present experiment the ISI–4,890 and ISI–1,390-msec conditions are similar to two of the conditions used by Shaffer and Shiffrin, and consistent with their results, a plateau in recognition accuracy was reached at those rates. In principle, if Shaffer and Shiffrin had decreased the time between pictures further, using the same recognition test, or if they had maintained the same ISIs but used a more difficult test (such as those used by Weaver, 1974; and Tversky & Sherman, 1975), an effect of ISI might have emerged.

Similarly, one of the results obtained in Experiment 1 may reflect a lack of test sensitivity. Presenting a picture instead of a blank interval during the ISI did not affect recognition accuracy when a traditional recognition test (with dissimilar distractors) was used. A more sensitive test of recognition, however, might pick up a difference in the level of encoding. This possibility was tested in Experiment 3.

Experiment 3

Recognition memory performance and reversal detection were measured following inspection conditions in which either a homogeneous field or a picture was presented during the ISI. If the occurrence of the ISI picture disrupts encoding of visual details (perhaps particularly visuospatial details that do not directly bear on the picture's meaning), then reversal detection should drop when the ISI contains a picture.

Method

Subjects. Subjects were 32 undergraduates from the Massachusetts Institute of Technology reporting normal or normal-corrected vision.

Stimuli and apparatus. The same pictures and viewing conditions were used as in Experiment 2, except that only two fields of the tachistoscope were employed.

Procedure. Subjects were tested individually and were randomly assigned to either the blank-ISI or picture-filled-ISI conditions. Subjects in both conditions viewed the pictures for 110 msec each with an ISI of approximately 5 sec. The same two ISI pictures employed in Experiment 1 were used; each was viewed by half of the subjects in the filled condition. The same order of presentation was employed in both conditions.

The procedure and viewing instructions were identical to those of the corresponding condition in Experiment 1. The recognition test and recognition instructions were the same as in Experiment 2. Once again subjects were informed about the reversal task only *after* having viewed the inspection sequence.

Results

Reversal detection was not significantly affected when a picture rather than a blank field filled the ISI. When a reversed target was recognized, the probability that the reversal was detected was .59 (*false yes* responses, .11) in the blank condition and .52 (*false yes* responses, .02) in the filled condition, $t(30) < 1$. After correction for guessing (see Footnote 4), the conditional probability of reversal detection was .59 and .51, respectively.

Unlike the corresponding condition in Experiment 1, a slight decrement in recognition memory was obtained in the picture-filled-ISI condition. The proportion of pictures recognized (corrected for guessing) was .92 and .81 for the blank- and picture-filled-ISI conditions, respectively, $t(30) = 3.64$, $p < .01$; the false alarm rates were .02 and .05. The mean number of normal and reversed pictures recognized (*yes* responses) was 7.4 and 7.2, respectively, in the blank condition and 6.8 and 6.4, respectively, in the filled condition. In neither condition was the difference between the two orientations significant (Wilcoxon matched-pairs tests).

The mean reaction time to correct *yes* responses was 1,012 msec (SD = 312 msec) in the blank condition and was 1,035 msec (SD = 212 msec) in the filled condition, $t(30) < 1$. Reaction time to recognition also did not differ between normal and reversed stimuli in either condition, $t(30) < 1$. For normal and reversed pictures, respectively, recognition response time was 1,000 msec (SD = 296 msec) and 1,024 msec (SD = 378 msec) in the blank condition and was 1,025 msec (SD = 210 msec) and 1,045 msec (SD = 215 msec) in the filled condition.

Discussion

Consistent with the results of Experiment 1, the present results indicate that the occurrence of a meaningful picture after a to-be-remembered picture cannot in itself account for the low level of recognition memory obtained following rapid continuous presentation. Moreover, the presentation of a repeating to-be-ignored picture during the ISI did not affect the subject's ability to detect a reversal. If anything, subjects in the picture-filled-ISI condition were better able to discriminate reversed from normal pictures, since the false reversed rate was only .02 as compared with .11 for the blank-ISI condition, and the mean reaction times in the two conditions were almost identical.

Although recognition accuracy decreased slightly when a picture was presented during the ISI, the proportion correct (.81) in that condition far surpassed that obtained for pictures shown at a similar duration in a continuous sequence. Accuracy in the latter case has been found to range only from .11 to .21 (present Experiments 1 and 2; Intraub, 1979; Potter & Levy, 1969). It should be noted that performance in the picture-filled-ISI condition did not differ significantly from that obtained in the ISI-4,890 msec (blank

Table 4
Mean Number of Correct Details, Minor Errors, and Gross Misinterpretations per Subject in the Picture-Filled-ISI and Blank-ISI Conditions

ISI	Correct details	Errors: Minor	Errors: Gross
Blank			
M	4.42	.95	.06
SD	1.21	.71	.19
Filled			
M	4.49	1.32	.03
SD	1.32	.73	.07

Note. ISI = interstimulus interval.

ISI) condition in Experiment 2, where recognition accuracy was .84. The implications of the slight decrease associated with a picture-filled-ISI in the present experiment were examined in Experiment 4.

Experiment 4

The slight decrement in recognition memory in the picture-filled-ISI condition in Experiment 3 might reflect a subtle degradation of the subject's initial understanding of each picture or a limit in the number of fine details available for encoding after the picture is no longer present. If so, the subject's immediate description of a briefly presented picture should be superior when the picture is succeeded by a blank field rather than an ISI picture. This hypothesis was tested in the following experiment.

Method

Sixteen subjects (Massachusetts Institute of Technology undergraduate volunteers) viewed each stimulus picture used in Experiment 3 for 110 msec and were then required to write a description of the picture in as much detail as possible. Half of the subjects were presented with a blank field following each picture and half were presented with one of the ISI pictures following each picture. They received as much time as they required to write a full description, before the next stimulus was presented.

Results and Discussion

Descriptions were generally several sentences long and often included schematic drawings. The time required for each ranged from about 30 sec to several minutes. A strict scoring procedure was employed, using a judge who was blind to condition. The groups were compared with respect to the number of correct details reported, the number of minor errors made, and the number of gross misinterpretations. These scores are shown in Table 4. No difference was obtained on any of these measures between groups (Mann-Whitney U statistics were 120, 87, and 127, respectively, $n_1 = n_2 = 8$). Subjects in both groups made both types of errors. Minor errors included such things as errors in color or describing a woman as smiling when actually her mouth was merely open showing teeth. Gross misinterpretations, which were infrequent, were defined as a distortion of the gist of the picture, for example, describing a ballet scene as a baseball game. Despite such errors, when a recognition test was subsequently administered to half of the subjects in each group, performance was perfect except for a single recognition failure (one failure out of 128 trials). No *false yes* responses were made.

What these results clearly show is that the occurrence of a repeating ISI picture does not degrade the quality of information available for encoding. If it did, then more minor errors of interpretation and fewer correct details should have been observed in the filled condition. Since presentation of the ISI picture reduced neither the ability to detect reversal (Experiment 3) nor the ability to describe the stimulus (Experiment 4), perhaps the slight decrease in recognition observed in Experiment 3 should be attributed to subjects' occasional failure to ignore the ISI picture.

Note that requiring the subject to immediately think about and write a description of each picture following presentation greatly enhanced performance on the recognition test as compared with performance obtained in Experiments 1–3. Perhaps this relatively intense activity strengthened the memory trace of each picture, functioning as a type of rehearsal. It should also be pointed out, however, that because the recognition test employed dissimilar distractors, remembering the written descriptions alone could have produced excellent recognition memory. As a final note it should be emphasized that in other research, using pictures from the same stimulus pool, the availability of a single verbal code (a one-word label) was found to have no effect on either recognition memory or free recall (Intraub, 1979). Enhancement in the present experiment was probably due to a more complex set of events than simply naming a picture and remembering the name.

General Discussion

Three issues were addressed regarding pictorial encoding: (a) the relative importance of stimulus duration and total study time (stimulus duration plus ISI), (b) the conditions in the visual field that disrupt encoding, and (c) the way in which disruption is manifested—as a change only in the number of pictures encoded, or as a change in the quality of encoding of each picture.

It was established that important aspects of the encoding process extend beyond the duration of the stimulus, continuing in the time between stimuli. Even when stimulus duration was only 110 msec, memory was extremely good when sufficient time between pictures was allowed. As the ISI was reduced, although recognition memory remained above chance even at the fastest rate of presentation, the ability to detect that a picture in the recognition test was mirror reversed decreased sharply, reaching chance at the three fastest rates. This indicates that the ISI was used in part to encode information concerning visuospatial attributes of the pictures. Encoding of this information occurred without benefit of additional fixations and continued beyond the period of iconic persistence. In fact, encoding of information necessary for reversal detection contined beyond a 620-msec ISI.

Not surprisingly, however, memory was better when pictures were presented for a full 5 or 6 sec each than when they were presented for the same total study time but with a duration of only 110 msec followed by a blank interval (Experiments 1 and 2). In the former case the subject could continually scan the picture while encoding additional details (Loftus, 1972; Loftus & Bell, 1975; Loftus & Kallman, 1979). What the present results show is that encoding of additional visual detail is not confined to the duration of the stimulus nor is it necessarily dependent on the number of eye fixations made on a picture. Both recognition accuracy and accuracy in detecting reversal decreased by a relatively small amount when duration alone was radically reduced from 5 sec to 110 msec. The decrease in performance on these tests was much more pronounced when duration was held constant and total study time was reduced.

The hypothesis that encoding is terminated by the occurrence of a substantial change in the visual field was not supported, nor was the suggestion that backward masking is the primary cause of poor memory following rapid continuous presentation of pictures. Presentation of a repeating picture during the ISI interfered only minimally with recognition memory and did not affect reaction time to recognize pictures, ability to detect reversal, or ability to report details of a picture (Experiments 1, 3, and 4). It seems that one factor that will affect whether or not a following visual event will disrupt processing of a previous picture is whether or not it also requires attention. There is evidence that attention to a nonvisual event can also disrupt memory for pictures. For example, Rowe and Rogers (1975) obtained a decrease in recognition memory and free recall of pictures when subjects were required to shadow (repeat) spoken letters during acquisition. Similarly, Loftus (1972) observed a decrease in recognition memory for pictures when subjects were required to count backwards by threes while viewing the inspection sequence.

In Experiment 2 it was found that increasing the time between to-be-remembered visual events led not only to the retention of more pictures but also to storage of more information per picture. Just which pictorial features are encoded and in what sequence remains to be clarified. Recognition tests (such as the reversal detection task) in which the similarity of targets and distractors is varied along other visual and semantic dimensions (cf. Mandler & Johnson, 1976) might reveal what type of information is encoded as the total study time for a picture is extended.

Reference Note

1. Intraub, H. *Selective attention for a subset of sequentially presented visual scenes.* Paper presented at the meeting of the American Psychological Association, New York, September 1979.

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