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DETECTION, PERCEPTION, AND MEMORY FOR RAPID SEQUENTIAL SCENES

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Three sets of experiments carried out by H. Intraub are reported:
I. Presentation rate and the representation of briefly glimpsed pictures in memory. 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 5890 msec interstimulus interval (ISI) were later recognized almost as welll 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.

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(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 processed pictures. (d) When the time between 110 msec pictures was decreased from 4890 to 1390, 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 visuo-spatial 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.

II. Rapid conceptual identification of sequentially presented pictures. When a sequence of pictures is presented as rapidly as 113 msec/picture, a viewer can detect a verbally specified target more than 60% of the time (Potter, 1976). In the present experiment sequences of pictures were presented at rates of 258, 172, and 114 msec/picture. A target was specified by name, by superordinate category, or by "negative" category (e.g., "the picutre that is not of food"). Although the probability of detection decreased as cue specificity decreased, even in the most difficult condition (negative category cue at 114 msec/picture) 35% of the targets were detected. When the scores from the three detection tasks were compared with a control group's immediate recognition memory for targets, immediate recognition memory was invariably lower than detection. The results are consistent with the hypothesis that rapidly presented pictures may be understood momentarily at the time of viewing and then be quickly forgotten.

III. Conceptual masking: The effects of subsequent visual events on memory for pictures. Three experiments studied the effects of voluntary and involuntary focus of attention on recognition memory for pictures. Experiments 1 and 3 tested the conceptual masking hypothesis which holds that a visual event will automatically disrupt processing of a previously glimpsed picture if that event is new and meaningful. Memory for 112 msec pictures was tested under conditions where the to-be-ignored 1.5 sec ISI contained a blank field, a repeating picture a new picture, a new nonsense picture, or a new inverted picture each time. The blank field, repeating picture, and new nonsense pictures did not disrupt memory as much as a new, meaningful picture, supporting the conceptual masking hypothesis. Experiment 2 studied voluntary attentional control of encoding by instructing subjects to focus attention on the brief pictures, all pictures, or the long pictures in a sequence. Recognition memory for pictures of both durations showed a striking ability of observers to selectively process pictures. The possible role of these effects in visual scanning are discussed.

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A later version of Section I will be published in Journal of Experimental Psychology: Human Learning and Memory, 1980, 6, 1-12; a version of Section II in Journal of Experimental Psychology: Human Perception and Performance, 1981, 1, 604-610; and a version of Section III is in press, Journal of Experimental Psychology: Learning, Memory and Cognition. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Defense Advanced Research Projects Agency or of the United States Government.

Presentation Rate and the Representation of Briefly Glimpsed Pictures in Memory

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Abstract

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 5890 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 4890 to 1390, 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 visuo-spatial 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 viewed for only a few seconds each 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 were addressed.

The first issue concerned 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 & Sheirer, 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 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 & Sheirer, 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 employed 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 concerned the stimulus conditions that cause a disruption of encoding when the rate of presentation is increased. It has been suggested that 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 pictures 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.

Third issue addressed was concerned with 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 (for example, 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 picture is presented during the ISI. 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 and fifty stimuli were chosen from a set of 252 color magazine photographs used by Intraub (1979a). (Stimuli for Experiments 1 - 4 were selected from this set). The cut-out 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° X 14°.

Design and procedure. The 150 pictures were presented in four different conditions. There were 20 subjects in each condition, run in groups of three or four. 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 5890 msec ISI during which a homogenous 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 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 the subjects in each condition. Approximately 2 minutes following presentation, a serial yes-no recognition test was administered. The test included 30 targets (selected equally often from the first and second halves of the sequence) randomly mixed with 30 distractors (pictures not previously seen). Distractors were chosen that did not bear a close resemblance to any of the stimuli. 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 employed and each set was presented to half 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 yeses* (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 eighteen to one[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.

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, $\underline{t}$ (38) = .43. This suggests that backward masking cannot account for the low level of recognition accuracy obtained following rapid continuous presentation. Consistent 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 experiment) would not be expected to elicit the same depth of processing as the novel pictures which 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 brief 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 employed 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 to serve as a more stringent test of visual memory because 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 which 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 employed 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° X 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 4890, 1390, 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 8-picture sample sequence to familiarize them with the viewing conditions.

The recognition test consisted of all 16 stimuli randomly mixed with 16 distractors which were also asymmetrical about the vertical. The stimuli were divided into two groups of eight. Each group was mirror-reversed for half 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 normal otherwise. Subjects were allowed as much time as necessary to make this decision and 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 yeses for each condition are shown in Table 2. A small significant decrease

Insert Table 2 about here

in recognition memory was obtained when duration was reduced from 5000 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, MSe = 14378.6, $p < .001$. An analysis of variance conducted on the proportion of yes responses and the proportion of false yeses for each subject revealed that overall, when duration was 110 msec, recognition memory was better than chance, F (1,45) = 450.7, MSe = 2037620.0, 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 differ-

Insert Table 3 about here

ence 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 1153 msec for normal pictures and 1234 msec for reversed pictures. This tendency for longer response times to reversed pictures did not reach significance, F (1,45) = 3.81, MSe = 243422.0, 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 both when stimulus duration and when total study time were 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 5000 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, $F(4,45) = 7.26$, $MSe = 1271.33$, $p < .001$.

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, $F(1,45) = 30.66$, $MSe = 20649.69$, $p < .001$, this was not the case in all the conditions. Whereas *all* subjects made more *correct yeses* than *false yeses*, 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-4890 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. While 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 1500 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, and Haber, 1970). This casts doubt on a description of recognition memory as a template-like matching process. While 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 visuo-spatial 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-4890 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 visuo-spatial characteristic such as left-right orientation. Indeed the observation that reversal did not affect recognition of a picture nor significantly inflate 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 seconds, 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 Shiffin experiment (as in the experiments presented in this paper), dissimilar distractors were employed. In the present experiment the ISI-4890 and ISI-1390 msec conditions are similar to two of the conditions used by Shaffer and Shiffin, and consistent with their results, a plateau in recognition accuracy was reached at those rates. In principle, if Shaffer and Shiffin 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, and Tversky and Sherman) 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 during the ISI, instead of a blank interval, 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 visuo-spatial 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 M.I.T. 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 run 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 yeses, .11) in the blank condition and .52 (false yeses, .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 1012 msec (SD = 312 msec) in the blank condition and was 1035 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 1000 msec (SD = 296 msec) and 1024 msec (SD = 378 msec) in the blank condition and was 1025 msec (SD = 210 msec) and 1045 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 (Experiments 1 and 2; Intraub, 1979a; and 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-4890 msec (blank 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 (M.I.T. 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 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 the subjects in each group performance was perfect, except for a single recognition failure (one failure out of 128 trials). No false yeses 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.

It should be noted 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.

Summary and Conclusions

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 visuo-spatial 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 continued beyond a 620 msec ISI.

Not surprisingly, however, memory was somewhat 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 & 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, & 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 total study time for a picture is extended.

Reference Note

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Footnotes

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[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 3 fixations per second on a picture.

[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).

Table 1

The Mean ($\bar{x}$) and Median (Md) Proportion of Correct Yeses, the Mean Proportion of False Yeses (FY), and the Mean Corrected Proportion of Pictures Recognized ($\bar{x}_c$) in each Condition

Stimulus duration (msec)	ISI (msec)	$\bar{x}$	Md	FY	$\bar{x}_c$
6000	0	.94	.97	.08	.94
110	5890 (blank)	.80	.83	.11	.77
110	5890 (filled)	.77	.83	.12	.73
110	0	.40	.37	.27	.21

Table 2

The Corrected Proportion of Pictures Recognized ($\bar{x}_c$), the Proportion of False Yeses (FY), the Conditional Probability of Reversal Detection (CPRD), the Corrected Condition Probability of Reversal Detection ($CPRD_c$), and the Proportion of Normal Pictures called Reversed (False Reversed - FR), for each condition

Stimulus duration (msec)	ISI (msec)	$\bar{x}_c$	FY	CPRD	$CPRD_c$	FR
5000	0	.96	.02	.82	.81	.03
110	4890	.84	.01	.58	.56	.17
110	1390	.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

Table 3

Mean Reaction Time to All Targets (RT_{all}) and Mean Reaction Time to Normal Targets (RT_{norm}) and to Reversed Targets (RT_{rev}), in each Condition (in Msec)

Stimulus duration	ISI	RT_{all}	RT_{norm}	RT_{rev}
5000	0	1270 (273)	1222 (276)	1315 (288)
110	4890	1162 (234)	1108 (208)	1221 (299)
110	1390	1171 (229)	1120 (210)	1242 (292)
110	620	1142 (332)	1040 (350)	1003 (287)
110	385	1141 (190)	1101 (197)	1173 (250)
110	0	1360 (249)	1377 (376)	1405 (231)

Note. Standard deviations are shown in parentheses.

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	Minor Errors	Gross Errors
Blank	4.42 (1.21)	.95 (.71)	.06 (.19)
Filled	4.49 (1.32)	1.32 (.73)	.03 (.07)

Note. Standard deviations are shown in parentheses.

Rapid Conceptual Identification of
Sequentially Presented
Pictures

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Abstract

When a sequence of pictures is presented as rapidly as 113 msec/picture, a viewer can detect a verbally specified target more than 60% of the time (Potter, 1976). In the present experiment sequences of pictures were presented at rates of 258, 172, and 114 msec/picture. A target was specified by name, by superordinate category, or by "negative" category (e.g., "the picture that is not of food"). Although the probability of detection decreased as cue specificity decreased, even in the most difficult condition (negative category cue at 114 msec/picture) 35% of the targets were detected. When the scores from the three detection tasks were compared with a control group's immediate recognition memory for the targets, immediate recognition memory was invariably lower than detection. The results are consistent with the hypothesis that rapidly presented pictures may be understood momentarily at the time of viewing and then be quickly forgotten.

Recognition memory for pictures is remarkably good. Hundreds and even thousands of complex pictures that are presented for a few seconds each, can later be recognized with better than 90% accuracy (Nickerson, 1965; Shepard, 1967; Standing, Conezio, & Haber, 1970). High levels of recognition memory performance are also obtained when pictures are presented for only about 100 msec each, as long as they are separated by substantial interstimulus intervals (ISIs). This occurs not only when the ISI contains a blank field (e.g., Rosenblood & Pulton, 1975), but also when it contains a familiar picture that repeats throughout the sequence (Intraub, 1980). If the ISIs are eliminated, however, and pictures are presented at the average rate of eye fixation (333 msec/picture) and faster (up to about 125 msec/picture), the normally excellent level of recognition memory obtained for pictures suffers dramatically, approaching the level of chance (Potter & Levy, 1969).

It is interesting that recognition memory should decline so precipitously when presentation rate mimics the rate at which visual scenes are normally fixated. Surely the visual system is not constructed so that the observer will scan the environment faster than each glimpsed scene can be analyzed. In normal vision, however, unlike the pictorial sequences used in those studies, there is considerable visual and conceptual overlap among successively fixated scenes. It has been proposed that this continuity allows expectancies to build up that serve to guide and to facilitate perception (e.g., Neisser, 1976). Based on this viewpoint it could be argued that the poor recognition memory performance obtained following rapid continuous presentation of pictures results from the observer's inability to identify the unrelated pictures. Potter (1975, 1976) has argued against this hypothesis, suggesting instead that in spite of the lack of continuity, virtually all pictures in such sequences are momentarily identified but are then immediately forgotten. The locus of interference is placed not on identification, but on the encoding processes necessary for retention.

In Potter's experiment sequences of magazine photographs were presented at rates ranging from 113 to 333 msec per picture. To determine if pictures are momentarily identified, the ability to detect a cued picture in a sequence was compared with a control group's recognition memory for pictures presented at the same rate. Cueing in the detection task was accomplished either by showing the target picture in advance or by describing it using a brief verbal title (e.g., "a road with cars"). Consistent with the hypothesis that each glimpsed picture is independently identified and understood, although not necessarily retained, detection accuracy far surpassed recognition memory at all rates, regardless of the type of cue employed. At the most rapid rate (~~that~~ which was considerably faster than the average rate of eye fixation), 64% of the target pictures were detected with a verbal cue, whereas only 11% of the pictures were remembered. The proportion of pictures detected was interpreted as reflecting the minimal proportion of pictures that was momentarily identified.[1] This interpretation implies that identification of successive visual scenes is possible even without the continuity and expectancy characteristic of normal viewing.

Expectancy, however, may not have been eliminated in Potter's experiments because the verbal cue used in the detection task may have raised probabilistic anticipations about the visual attributes of the target. The high level of detection accuracy may simply reflect the fact that the cued picture was perceived more often than other pictures in the sequence. Similarly, it has been suggested that the "higher order" conceptual information provided by the verbal cues in Potter's experiments served to guide and facilitate the processing of "lower-order" information, such as specific object identity (Carr & Bacharach, 1976; Neisser, 1976). If this is the case, then support for Potter's momentary identification hypothesis would be reduced to an artifact.

One way to determine if expectancy alone causes detection accuracy to surpass recognition memory is to employ a detection task in which a picture is cued <u>without</u> giving the observer any specific information about its physical or conceptual characteristics; thereby eliminating perceptual priming. In the present experiment two different detection tasks using non-specific cues were employed to this end: "negative cueing" and "category cueing". Sequences were constructed that consisted of a diverse set of pictures belonging to a single general category and one picture that was not a member of that category. Subjects in the negative cue condition were provided with the name of the general category of the sequence and were instructed to detect and to describe the picture that did not belong. In principle, in order to detect the negatively cued target picture, the subject would have to momentarily identify and categorize all pictures up to and including the target.

Although a negative cue should effectively limit any effect of expectancy there was some concern about the subject's ability to carry out the task for another reason. A negative decision is a relatively lengthy and difficult decision to make (e.g., Just & Carpenter, 1971). Under the time pressures of rapid presentation, a negatively phrased verbal cue could reduce detection ability for this reason alone. To circumvent this problem, a positive detection task using a non-specific cue was also employed. This constituted the category cue condition. Detection was cued in this case by providing the subject with the name of the superordinate category to which the target picture belonged. A category cue, while providing more information about the target than a negative cue, provides little advance information about the visual characteristics or identity of the target. In a third detection task, the target was cued by its specific name. This task, which is comparable to Potter's verbal cue task, was included as a replication.

A control group's immediate recognition memory performance was used for comparison with each of the three detection tasks. Because Potter's momentary identification hypothesis states that more pictures are identified than are remembered, it is important to avoid using any test procedures that might artifactually lower recognition memory performance when testing this hypothesis. To make the recognition test as sensitive to memory for the target as possible, the following three provisions were introduced. (a) Unlike Potter's recognition test in which <u>all</u> the pictures from a sequence were tested (yielding a 32-item test, including the distractors), in the present experiment only the target picture and one other picture from the sequence were tested. This procedure eliminated the interference that a series of relatively long tests might provide. (b) To enhance recognition memory, the two distractors (new pictures) used in the brief 4-item test were neither visually nor conceptually similar to the target. (c) Furthermore, to make a more precise comparison between detection and recognition memory than in Potter's experiments, detection accuracy was compared with recognition memory for the target itself, rather than being compared with overall recognition memory performance.

If detection accuracy surpassed recognition memory in Potter's experiments because of expectancy, then the difference between detection and memory should be eliminated when non-specific detection cues are used (i.e., in the negative cue and category cue conditions). If detection superiority is maintained in the non-specific cue conditions then this would indicate a striking ability of the observer to momentarily analyze and understand the contents of successively glimpsed scenes.

Method

Subjects. Subjects were 96 M.I.T. undergraduates reporting normal or normal-corrected vision.

Materials. The stimuli were color magazine photographs of objects and scenes used by Intraub (1979, 1980). Eleven sequences of 12 pictures each were photographed, two frames per picture, using 16 mm movie film. Eleven pictures in each sequence belonged to a single general category (transportation, house furnishings and decorations, mechanical devices, food, body parts, people, animals, fruits and vegetables, and household appliances and utensils). The twelfth was from a different category, and appeared in a serial position between 2 and 11. This picture will be referred to as the target. Pictures within each general category were selected so that they were as visually dissimilar as possible. For example, pictures of "animals" included creatures as diverse as a frog, a giraffe, a butterfly, and a dog; pictures of "house furnishings and decorations" included such items as a chandelier, pillows, and a chair. The target did not differ distinctively in size or in overall coloration from other pictures in the sequence.

Two sets of 11 sequences were made, identical except that a different collection of targets appeared in each. Each set was presented to half the subjects in every condition, so that twenty different target pictures were tested over the course of the experiment. Slides of the pictures (35mm) were employed in the recognition test.

Apparatus. Sequences were projected on a screen using an L-W variable speed 16 mm movie projector. In order to obtain reaction times in the detection tasks, a bright white square was photographed in the lower corner of a frame, 8 frames prior to the first picture in the sequence. The projected image of the square illuminated a photocell that triggered a digital reaction timer. The timer was stopped when the subject pressed a response button. A Kodak Carousel 35 mm slide projector was used to project targets and distractors in the recognition test. Size and illumination were approximately the same in the recognition test as in the inspection series. Pictures varied slightly in size; on the average, the visual angle subtended by a picture was approximately $5^{\circ} \times 5^{\circ}$.

Design and procedure. The three detection tasks and the recognition memory task were all tested at each of three presentation rates - 114, 172, and 258 msec per picture, using a between subjects design. Eight subjects were assigned to each of the 12 conditions. Subjects were presented with one sample sequence to familiarize them with the task and ten experimental sequences. For half the subjects in each condition the sequences were run in reverse; thus, each target appeared in 2 different serial positions. Film direction and target set were counterbalanced in each condition.

Target Detection. Subjects in the detection groups were provided with the target cue prior to the start of each sequence. They were instructed to press the response button as soon as they saw the cued picture and to describe it briefly. Detection of the target was cued by specific name, by superordinate category, or by "negative" category. For example, if the general category of the sequence was "house furnishings and decorations", and the target was a picture of a butterfly, subjects in the specific name cue condition were told to "look for a butterfly", in the category cue condition they were told to "look for an animal," and in the negative cue condition they were told to "look for a picture that is not of house furnishings and decorations."

Recognition Memory. Subjects in the recognition memory groups were instructed to attend to each picture in the sequence and to try to remember as many as possible. For this group, no mention of categories or "odd" pictures was made. Following presentation of each sequence a 4-item serial yes-no recognition test was immediately administered. The two old pictures were always the target picture and one non-target from the sequence. Non-targets preceding and following the target in the sequence were tested equally often (the pictures immediately preceding and following the target in the sequence were not tested). Two new pictures (distractors) were included in each test. One distractor (the similar distractor) was a picture belonging to the general category of the sequence. The other distractor (the dissimilar distractor) was a picture that belonged neither to the general category of the sequence, nor to the same category as the target. This testing procedure allowed for maximum test sensitivity for recognition of the target and allowed for assessment of guessing strategies.

Although no mention was made of "categories" or "odd pictures" in the recognition memory condition, the comments of a pilot subject indicated that subjects might in fact spontaneously notice the "category plus odd picture" arrangement of the sequences. To determine if this was the case, at the end of the session each subject in the recognition memory condition was asked to write a general description of the sequences shown in the experiment.

Scoring. In Potter's (1975, 1976) experiments the subject pressed a response key to indicate detection of the target in the sequence. A response was considered correct if it occurred between 250 and 900 msec following target onset. Because presentation was continuous this leaves some uncertainty about whether the response was indeed made to the target or if it was made to another picture. This problem was eliminated in the present experiment by requiring the subject to describe the target. The description had to contain information specific enough to assure that the subject had identified the target in order for the response to be counted.

In the specific name cue condition, subjects were required to provide some specific information about the visual attributes of the target. For example, consider the target cue "chair". The chair in question was a reddish-brown leather easy chair with buttons on the back support. Responses such as "upholstered", "easy chair", "arm chair", "leather with buttons", "reddish-brown", or "side view with back support on right" were all considered correct. If the only description offered was a property inherent to all chairs (e.g., it had a back) the response was not counted as correct (this type of response was rare). In the category and negative cue conditions, where the specific identity of the object had not been provided, either a specific name or a description was counted as correct. For example, if the target was a brown shaggy dog, the responses "dog" and "shaggy brown animal" were accepted.

Results

Detection accuracy and recognition memory performance will be reported separately and then compared.

Detection. Subjects were able to detect and describe target pictures at all three presentation rates even when they were provided with only a negative cue. The proportion of targets detected using name, category, and negative cues at each rate is shown in Table 1. Reaction times for those responses are shown in Table 2.

Insert Tables 1 and 2 about here

A two-way analysis of variance (Cue Type X Presentation Rate) revealed an improvement in detection ability when slower presentation rates were used, F (2,63) = 13.39, MSe = .0314, $p < .001$, and when more specific cues were used, F (2,63) = 16.11, MSe = .0314, $p < .001$. A significant interaction between rate and cue type was not obtained, F (4,63) = 1.60, although the interaction approached significance in a trend analysis, F (2,63) = 2.66, $p < .10$. A similar analysis of the reaction times revealed that subjects responded more quickly as more specific cues were used, F (2,63) = 13.00, MSe = 23056.59, $p < .001$. Unlike the accuracy scores, however, reaction time was unaffected by changes in presentation rate. An interaction was not obtained in either the analysis of variance or a trend analysis, $F < 1$, both cases.

Most detection failures were misses: .16, .32, and .35, for the name, category, and negative detection tasks, respectively. The proportion of trials that were counted as failures because of erroneous or non-specific descriptions was .02, .06, and .08, respectively.[2] In no case did a subject report detecting a target without being able to provide a description; that is, no subject said, "I saw something that was <u>not</u> an animal, but I don't know what it was or what it looked like".

<u>Recognition memory</u>. The mean proportion of target pictures and the mean proportion of non-target pictures recognized at each rate are shown in Table 1, corrected for guessing.[2] A two-way analysis of variance, Picture Type (target or non-target) X Presentation Rate, with repeated measures on picture type, was conducted. As expected, fewer pictures were recognized as faster presentation rates were used, $\underline{F}$ (2,21) = 6.19, MSe = .3963, $p < .001$. No difference in the corrected proportion recognized was obtained between target and non-target pictures, $\underline{F} < 1$, nor was there an interaction between picture type and presentation rate, $\underline{F} < 1$. Non-targets preceding and following the target picture in the sequence were remembered equally often.

There were virtually no <u>false yeses</u> (.02) made to the <u>dissimilar distractor</u> (the target picture's control for guessing). In fact, only one subject committed this type of error. This shows that subject's did not simply respond "yes" to <u>any</u> test picture that did not belong to the general category of the sequence. As would be expected following rapid presentation of 11 pictures from the same category, <u>false yeses</u> to the <u>similar distractor</u> (the non-target picture's control for guessing) were relatively abundant (.25).

At the end of the session, when the subjects were asked to describe the sequences they had just seen, all subjects reported that pictures were grouped by category and 83% specifically reported a "category plus odd picture" arrangement.

Detection versus recognition memory. Contrary to the expectancy hypothesis, more pictures were detected during presentation than were remembered immediately following presentation regardless of the specificity of the detection cue (see Table 1), thus providing strong support for the momentary identification hypothesis. Detection accuracy for each cue type was individually compared with recognition accuracy for the target picture, collapsing over rate. Planned comparisons revealed that in each case, significantly more pictures were detected than were remembered; F (1,84) = 64.00, 16.00, and 9.00 with MSe = .0334 and $p < .001$, when recognition memory was compared with detection by name, by category, and by negative category, respectively. A two-way analysis of variance (Task X Presentation Rate) including all four tasks revealed no interaction between task and rate, F (6,84) = 1.21. The main effects of task and presentation rate were both highly significant, F (3,84) = 19.97, MSe = .6676, $p < .001$; F (2,84) = 24.39, MSe = .8154, $p < .001$, respectively.

Discussion

The results show that observers possess a striking ability to identify and understand unrelated pictures at presentation rates equal to or faster than the average rate of eye fixation. Detection of verbally cued pictures was superior to a control group's immediate recognition memory for the same pictures even when a highly sensitive test of recognition memory was employed. This supports Potter's (1976) hypothesis that pictures are momentarily understood but immediately forgotten during rapid presentation.

Furthermore, the results clearly demonstrate that expectancy alone cannot account for the superiority of detection ability over recognition memory. Detection was superior even when the target had been negatively cued; that is, even when no specific information regarding the visual or conceptual characteristics of the target was provided (e.g., "detect and describe a picture that is not of an animal"). In fact, at the rate of presentation that most closely approximates the average rate of eye fixation (258 msec/picture), 79% of all targets were detected and described on the basis of a negative cue, whereas only 58% of all target pictures were remembered immediately following presentation.

Additional support for the momentary identification hypothesis is provided by the recognition memory subjects' descriptions of the sequences. These subjects were not given any hint that the sequences contained diverse pictures from a general category and one picture that did not belong. They were simply instructed to pay attention to each picture in the sequence and to try to remember them all. Yet, when asked to describe the sequences at the end of the session, all subjects reported that pictures were grouped by category, and 83% wrote specifically that the sequences were arranged in a "category plus odd picture" fashion. Although their immediate recognition memory was relatively poor, these subjects had apparently momentarily identified and categorized the pictures during presentation. In their descriptions a few subjects indicated that they could have adopted a strategy to remember the odd picture, but that doing so would have disrupted their ability to remember the other pictures in the sequence. The observation that non-targets preceding and following the target were remembered equally often suggests that, consistent with those reports, subjects did not adopt that strategy.

One might still argue that expectancy played some role in detection because, overall, detection accuracy increased as more specific cues were used. According to this view, expectancy may have increasingly facilitated perception of the target as more specific cues were provided. There is, however, an alternate explanation of the difference among the three detection tasks. The process of deciding that the cue and the target picture match increases in complexity as less specific cues are provided.

Consistent with this consideration, responses were fastest when the target was cued by specific name, and slowest when it was cued by negative category. If pictures are identified only momentarily during presentation, then a decision process requiring relatively little time is more likely to be completed before attention is drawn to the next pictures. Thus, detection by specific name is more likely to be successfully completed than detection by category or by negative cue. In fact, when the time per picture was increased to 258 msec, detection by negative cue was almost as accurate as detection by specific name, yet the response required an average of 150 msec longer.

Of course the results do not imply that expectancy is not important in normal visual perception. What they do show is that even without the continuity characteristic of normal vision, successively glimpsed scenes can be understood surprisingly well. This ability may function as a monitoring system in normal vision. For example, momentary identification of each "fixated" scene may play a role in controlling placement of subsequent eye fixations (for an example in reading, see Rayner, 1979). Establishment of a relatively stable memory representation of a scene requires more than identification (contrary to earlier suggestions, cf. Haber, 1970). Storage requires implementation of encoding processes than can even extend beyond the duration of the stimulus (Intraub, 1979, 1980; Potter, 1976; Tversky & Sherman, 1975; Weaver, 1974; Weaver & Stanny, 1978). During rapid presentation of unrelated scenes, when the observer attempts to analyze and remember them all, these encoding processes are probably disrupted when attention shifts from one picture to the next pictures in the sequence (Intraub, 1980 in press; Potter, 1976; Potter & Levy, 1969). At extremely rapid presentation rates apparently the primary locus of interference is not at the level of conceptual identification but at the level of memory.

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Footnotes

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[1]By "identification" it is meant the point at which the main theme of the picture is correctly determined. This does not imply covert naming of the pictures (which would be unlikely at the rapid rates of presentation employed), since pictures can be conceptually understood before they are named (Potter & Faulconer, 1975).

[2]Some of the erroneous responses in the category and negative detection conditions nonetheless might reflect analysis of the target. An example of this type of response is describing a "long-legged" dog as a "deer." Particularly in the negative

cue condition, where the target could be virtually anything, the response "deer" would seem to indicate some analysis of the target - like the target, a deer is a brownish four-legged creature. When more lenient scoring was employed, category and negative detection scores increased slightly. For the slow to fast rates respectively the category detection scores were .70, .72, and .48 and the negative detection scores were .80, .63, and .40.

[3]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 correct _yes_ responses to old pictures, and FY is the proportion of _yes_ responses to distractors (_false yeses_). The proportion of negative pictures and general category pictures recognized were corrected separately using the appropriate distractor (i.e., the _dissimilar distractor_ was employed in the target picture correction, and the _similar distractor_ was employed in the non-target picture correction).

Table 1

The Proportion of Pictures Detected by Name, Category (Cat), and Negative Category (Neg); and the Proportion of Target Pictures (Target) and Non-Target Pictures (Non-Target) Recognized at each Rate of Presentation

Rate (msec/picture)	Detection			Recognition Memory[a]	
	Name	Cat	Neg	Target	Non-Target
258	.89	.69	.79	.58	.58
172	.86	.71	.58	.49	.33
114	.71	.46	.35	.19	.34

[a] Recognition scores were corrected for guessing (see Footnote 2).

Table 2

The Mean Reaction Time for Detection by Name, Category (Cat), and Negative Category (Neg) at each rate of presentation

Rate (msec/picture)	Reaction Times (in msec) Name	Cat	Neg
258	467(38)	615(116)	619(72)
172	485(52)	595(55)	728(186)
114	516(116)	670(259)	786(258)

Note. Standard deviations are shown in parentheses.

Conceptual Masking: The Effects of Subsequent Visual Events on Memory for Pictures

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Abstract

Three experiments studied the effects of voluntary and involuntary focus of attention on recognition memory for pictures. Experiments 1 and 3 tested the *conceptual masking* hypothesis which holds that a visual event will automatically disrupt processing of a previously glimpsed picture if that event is new and meaningful. Memory for 112 msec pictures was tested under conditions where the to-be-ignored 1.5 sec ISI contained a blank field, a repeating picture, a new picture, a new nonsense picture, or a new inverted picture each time. The blank field, repeating picture, and new nonsense pictures did not disrupt memory as much as a new, meaningful picture, supporting the conceptual masking hypothesis. Experiment 2 studied voluntary attentional control of encoding by instructing subjects to focus attention on the brief pictures, all pictures, or the long pictures in a sequence. Recognition memory for pictures of both durations showed a striking ability of observers to selectively process pictures. The possible role of these effects in visual scanning are discussed.

Stimulus factors such as duration, presentation rate and visual similarity of stimuli have all been shown to affect memory for pictures (e.g., Intraub, 1979, 1980; Nelson, Reed, & Walling 1976; Potter, 1976; Weaver & Stanny, 1978). The present research was motivated by questions concerning the observer's control over picture processing and the factors that might limit this control. One potential factor, proposed by Potter (1976) is conceptual masking. The conceptual masking hypothesis is concerned with the early stages of picture processing; processing that is initiated during the first eye fixation made on a picture or scene. According to the hypothesis, a picture is rapidly understood and is held for a few hundred milliseconds in a short-term conceptual store while it is consolidated in memory. The information at this stage is very unstable and may be lost if a new picture is quickly presented. This occurs because the new picture itself elicits conceptual processing thus replacing the previous item in the short-term conceptual store.

The hypothesis is based upon research in which single fixations and the dynamic, sequential activity of visual scanning are mimicked through the use of tachistoscopic presentation and rapid sequential presentation of pictures. When unrelated pictures are presented at rates that approximate the average fixation frequency of three per second and faster, and recognition memory is tested immediately, subjects can remember very few pictures (e.g., Intraub, 1979, 1980; Potter & Levy, 1969). It was suggested that poor memory for rapidly presented, unrelated pictures may be due to an inability to identify the pictures, perhaps due to visual masking (Rosenblood & Pulton, 1975; Shaffer & Shiffrin, 1972). More recent research, however, rules out the visual masking hypothesis by demonstrating that recognition memory for a series of briefly glimpsed pictures is very good when pictures are presented with interstimulus intervals (ISIs) that contain a visual noise mask (Potter, 1976) or a familiar picture that repeats throughout the sequence (Intraub, 1980). Furthermore, visual search experiments indicate many more pictures are momentarily identified during rapid continuous presentation than are remembered later (Intraub, 1981; Potter, 1975, 1976).

In one set of experiments a target picture in a rapidly presented sequence was cued by providing the subject either with the picture itself or with a brief verbal title (e.g., "a road with cars", Potter, 1975, 1976). In another experiment to minimize expectancy effects the target picture was cued by providing the subject with its superordinate category or a negative cue (e.g., "a picture that does not belong to the category 'transportation'," Intraub, 1981). In all cases detection accuracy yielded relatively good performance as compared with recognition memory for the same pictures. The apparent rapid loss of momentarily held information was attributed to conceptual masking of each picture by the next. According to this view, while many pictures are identified, only those that can be consolidated prior to onset of the next picture will be remembered at the end of the sequence.

The extent to which conceptual masking is automatic remains unclear. Given that the acquisition of a picture's general concept or "gist" is obtained very rapidly (e.g., Biederman, Rabinowitz, Glass & Stacy, 1974; Intraub, 1981b, 1981b; Potter, 1975, 1976), the observer may not be able to suppress these processes of identification resulting in conceptual masking if the meaningful visual events are close enough in time. Potter (1976) raised the possibility that an observer would not be able to disattend a new picture in a sequence. The present experiments address this issue. Experiment 1 studies the extent to which selective processing of individually glimpsed pictures can be voluntarily controlled when new pictures are <u>immediately</u> presented. Recent experiments have shown that observers provided with attention instructions can selectively process particular pictures in a series when cued with a warning tone (Weaver & Stanny, 1978) or a post-cue (Graefe & Watkins, 1980; Watkins & Graefe, 1981). Those studies, however, used relatively long stimulus durations and conditions in which the to-be-remembered pictures were not immediately followed by new pictures. Experiment 2 examines the effect of selective attention instructions on memory for sequentially presented pictures under conditions in which conceptual masking would be expected. Experiment 3 addresses the issue of whether or not the masking proposed by Potter is actually "conceptual" in nature, i.e., if it is identification of the _meaning_ in a new input that leads to a disruption of memory.

Experiment 1

To determine the effect that immediate presentation of a _new_ picture has on memory for briefly glimpsed pictures in a sequence, pictures were presented for 112 msec each with a 1.5 sec ISI that contained a new picture each time. Subjects were instructed to attend to the 112 msec pictures and to remember as many as possible. Memory under this condition was compared with that obtained when the ISI contained a familiar picture that repeated throughout the sequence, and when the ISI contained a blank field. If encoding of a glimpsed scene is automatically terminated by the onset of a new scene, then recognition memory should suffer dramatically when the ISI contains a new picture. In principle, it should approach the poor performance obtained following continuous presentation (no ISI). (Note that using pictures from the same stimulus pool as Experiment 1 and a duration of 110 msec per picture, Intraub [1979, 1980] obtained recognition memory scores of between 19% and 21% correct for set sizes of 150, 20 and 16 continuously presented pictures.) If new pictures can be disattended, then recognition memory should equal the condition in which a repeating picture is presented during the ISI.

Method

Subjects. Subjects were 36 Massachusetts Institute of Technology undergraduates who were paid for their participation. All reported normal or corrected vision.

Materials and apparatus. The stimuli were color magazine photographs of 1-2 main objects which were cut out and rephotographed on a plain gray background. They belonged to a diverse range of categories (e.g., people, animals, food, etc.) and were used previously by Intraub (1979, 1980). These were photographed, using single frame photography, on 16 mm color movie film. The sequences were projected onto a standard movie screen using an L-W variable speed 16 mm projector at 18 frames per second. For the recognition test, 35 mm slides of the stimuli were presented using a Kodak carousel projector. The pictures subtended a visual angle of approximately $12^{\circ} \times 12^{\circ}$.

Design and procedure. Twelve subjects took part in each of three conditions, and were run singly or in pairs. In all conditions, 16 pictures were presented for 112 msec each with a 1.5 sec ISI. There were two sets of 16 stimuli, each viewed by half of the subjects in each condition. In the changing-ISI condition, a new picture was presented during the ISI each time. The 112 msec pictures in one version were used as the ISI pictures in the other version, and vice versa. In the repeating-ISI condition, a single picture was repeated during each ISI. Subjects were shown the picture in advance. Two different ISI pictures chosen from the same stimulus pool were used (these pictures were different than the ones used in Intraub's, 1980, previous repeating-ISI conditions). Each was presented to one half of the subjects in the repeating-ISI condition. In the blank-ISI condition, a homogenous gray field was presented during the ISI.

All subjects were presented with a 6-picture practice sequence and a practice recognition test prior to viewing the experimental sequence. In the repeating-ISI condition subjects viewed the same ISI picture in the sample as they would see in the experimental sequence. Following presentation of the experimental sequence, a 32-item serial recognition test was administered that included the 16 stimuli randomly mixed with 16 distractors (new pictures). The order of presentation of pictures in the test was reversed for half the subjects in each condition. The distractors were from the same pool of pictures, but were chosen to avoid those that would be highly confusable with the targets in terms of conceptual content. That is, although both targets and distractors fall into the same superordinate categories (e.g., people or foods) pictures with the same specific object identity were not used (e.g., two cowboys, two apples etc.).

All subjects were instructed to fixate on the center of the screen at all times during presentation and to pay attention to the briefly presented pictures. The presentation rate was chosen to be fast enough so that subjects would have to remain vigilant not to miss the brief pictures. In the changing- and repeating-ISI conditions, subjects were instructed to try to ignore the ISI pictures. Subjects in all conditions were told to use the ISI to memorize the brief pictures which would then be presented in a recognition test. The brief duration and rapid rate of presentation made it seem unlikely that subjects would (or even could) adopt a peripheral strategy for ignoring the ISI pictures by closing their eyes quickly enough to avoid seeing the ISI pictures and opening them again in time for the next stimulus. However, to check this possibility the experimenter was positioned so that he could watch the subjects' faces during presentation. This observation as well as strategy descriptions provided by a subset of subjects in Experiments 1 and 2 indicated that subjects were following instructions. Subjective reports included such terms as "mentally blocking" ISI pictures or "concentrating my thinking" on the brief pictures. For the recognition test, subjects were instructed to write "yes" if they were reasonably sure they had seen a picture before and "no" otherwise.

Results and Discussion

Presentation of a new picture during the ISI disrupts memory for briefly glimpsed pictures more than presentation of a familiar, repeating picture, but does not reduce it to the low level obtained following rapid continuous presentation. The proportion of pictures recognized, the proportion of false alarms, and the proportion recognized corrected for guessing[1] in the blank-, repeating-, and changing-ISI conditions are shown in Table 1.

Insert Table 1 about here

A one-way analysis of variance on the corrected proportion recognized showed that the conditions differed significantly, $F(2,33) = 11.02$, $MSe = .0194$, $p<.001$. Similar to Intraub (1980), only a small memory decrement was obtained when the ISI contained a repeating picture rather than a blank field, showing that visual masking of one picture by the next is not the primary cause of poor performance following rapid continuous presentation. A Dunn post-hoc comparison showed that this difference was not significant. Also, memory performance was not differentially affected by the two picture masks used in the experiment (both yielded corrected scores of 80% recognized). A significant drop in performance was obtained when a new picture was presented during the ISI rather than a repeating picture, $p<.05$ (Dunn post-hoc comparison). The level of performance, however, remained relatively high (63% correct, corrected for guessing). Although disrupting processing to some degree, presentation of a new picture apparently does not terminate encoding or prevent the subject from using the ISI to continue processing a briefly glimpsed picture. Memory did not approach the low level obtained following continuous presentation of pictures from the same pool shown at a similar duration (i.e., approximately 20% remembered, see Intraub, 1979, 1980). Experiment 2 examined the extent to which the observer can voluntarily control encoding to selectively process brief and long pictures in the changing-ISI condition.

Experiment 2

To study the ability to voluntarily control encoding of sequentially presented pictures, subjects were presented with a sequence of alternating 112 msec and 1.5 sec pictures (the changing-ISI sequences described in Experiment 1). They received one of three attention instructions; attend only to the brief pictures, attend to all pictures, or attend only to the long pictures. Expected and incidental recognition memory tests were used to evaluate memory for the 112 msec and 1.5 sec pictures following each attention instruction.

Method

Subjects. Subjects were 72 undergraduates from Massachusetts Institute of Technology. All reported normal or corrected vision and were paid for their participation.

Materials and apparatus. The apparatus was the same as in Experiment 1. The two changing-ISI sequences described in Experiment 1 were used. The 16 pictures that served as long pictures in one sequence served as brief pictures in the other sequence and vice versa. Each sequence was shown to half the subjects in each of the six conditions described below.

Design and procedure. There were three attention instruction groups with 24 subjects in each. Depending on group, subjects received one of three attention instructions concerning which pictures in the sequence to focus their attention on: a) attend to the brief pictures, b) attend to all pictures, or c) attend to the long pictures. They were told that memory for those pictures would be tested using a serial recognition test.

All subjects viewed a short sample sequence and received a recognition test that always tested memory for the pictures specified in the attention instruction. In the actual experiment two recognition tests were administered. The first test included 16 long or brief pictures (depending on condition) randomly mixed with 16 dissimilar distractors. For half of the subjects in each attention condition, the first test tested memory for the long pictures only, regardless of which pictures had been specified in the attention instruction. For the other half of the subjects, the first test tested memory for the brief pictures only, regardless of which pictures had been specified in the attention instruction.[2] Just prior to the recognition test, all subjects were informed about which pictures would actually be tested. After this test subjects received a second recognition memory test. This one tested memory for the alternate set of pictures, and included 8 of the 16 old pictures as target items and 8 dissimilar distractors. Again, prior to the test subjects were told which pictures (long or brief) to expect. Thus, when a subject's first test was for the long pictures, that subject's second test was for the brief pictures and vice versa. In this way, the effect of each attention instruction could be looked at both across and within subjects. The same testing instructions and procedures were used as in Experiment 1.

Results and Discussion

The results demonstrate a pronounced effect of attention instruction on recognition memory for both the 112 msec and 1.5 sec pictures. The scores obtained on the first recognition test, corrected for guessing are depicted in Figure 1. The raw scores and false alarm rates for those conditions are shown in Table 2.

Insert Figure 1 and Table 2 about here

A two-way analysis of variance (Picture Duration X Attention Instruction) on the guessing corrected scores revealed significant main effects of picture duration (favoring the 1.5 sec pictures) and attention instruction, F (1,66) = 61.17, MSe = $p<.001$ and F (2,66) = 4.76, MSe = .0252, $p<.001$, respectively. A strong interaction of picture duration and attention instruction was obtained, F (2,66) =

43.64, MSe = .0252, p<.001. As attention instruction changed from attend to the brief pictures, to attend to all pictures, to attend to the long pictures, memory for the 112 msec pictures decreased and memory for the 1.5 sec pictures increased. Independent one-way analyses of variance for the 112 msec pictures and the 1.5 sec pictures, showed that the effect of attention instruction on memory was significant for pictures of both duration, F (2,33) = 36.36, MSe = .0244, p<.001, and F (2,33) = 12.80, MSe = .0261, p<.001, respectively.

The same pattern of scores can be seen in the results of the second recognition test. That is, when the same subjects were tested on the alternate picture set (e.g., brief versus long) the same effect of attention instruction was obtained. The corrected recognition scores obtained in the secondary test are shown in Figure 2. The raw scores and false alarm rates are shown in Table 2.

Insert Figure 2 about here

A two-way analysis of variance again revealed significant main effects of picture duration, F (1,33) = 30.00, MSe = .05, p<.001, and a significant interaction, F (2,66) = 17.80, MSe = .05, p<.001. There was no main effect of attention instruction, F<1. Independent one-way analyses of variance for the 112 msec and 1.5 sec pictures, showed significant effects of attention instruction on memory for pictures of both durations, $\underline{F}$ (2,33) = 32.80, MSe = .05, p<.001 and $\underline{F}$ (2,33) = 11.00, MSe = .05, p<.001, respectively.

The results show that processing of a briefly glimpsed picture can continue during presentation of a new meaningful picture and that observers have considerable control over the encoding process. Attention instruction had a large effect on recognition memory, not only for briefly presented pictures but for pictures that had remained in view for 1.5 seconds. Although the magnitude of the effect is large, Experiment 1 suggests a limit on the voluntary control of encoding during sequential presentation. Under "attend to brief" instructions in that experiment, subjects in the changing-ISI condition remembered fewer brief pictures than subjects in the repeating-ISI condition. Apparently the new ISI pictures interfered with processing. A form of the conceptual masking hypothesis might account for the difference between these conditions. Experiment 3 tests two alternate explanations of the memory deficit in the changing-ISI condition.

Experiment 3

Contrary to the conceptual masking hypothesis, one alternate explanation of the decrease in memory in the changing-ISI condition is that it may be an artifact of the number of pictures presented in that condition. Although both repeating- and changing-ISI subjects were presented with 16 briefly presented pictures to remember, and both were instructed to ignore information presented during the ISI, subjects in the changing-ISI condition saw a total of 32 new pictures (including the ISI-pictures) whereas the other group saw a total of 17 (including the repeating picture). The lower recognition memory scores in the changing-ISI condition may reflect confusion on the recognition test due to the relatively large set of pictures viewed, rather than to conceptual interference during presentation.

To test this hypothesis, a new step was introduced into the repeating-ISI condition so that subjects in that condition would also view 16 to-be-ignored pictures. Just prior to the experimental sequence, subjects were presented with a monitoring task. They were shown a target picture and were told that it would appear briefly during a sequence of pictures. The continuous sequence contained all 16 ISI-pictures from the changing-ISI condition presented for 1.5 sec each. They were told to focus attention on remembering the target and to try to prevent the long pictures from distracting them. The target always appeared after the last item in the sequence. This was followed by the repeating-ISI experimental sequence and recognition test. In this way memory could be studied both when a set of 16 to-be-ignored pictures were presented immediately prior to the stimulus set and when 16 to-be-ignored pictures were presented so that each one immediately followed a stimulus picture. If the memory deficit in the changing-ISI condition in Experiment 1 was due to the greater number of pictures viewed leading to confusions on the recognition test, then no difference between groups should be obtained with the inclusion of the monitoring task. If the difference was due to interference with encoding caused by presentation of new pictures in the ISIs, the difference in memory performance should replicate despite presentation of the monitoring task.

If the difference between groups is maintained when repeating-ISI subjects also view the set of 16 to-be-ignored pictures, the conceptual masking hypothesis would provide one explanation of its cause. An alternate hypothesis, however, is that interference caused by presentation of a new picture during the ISI may not be due to the conceptual attributes of the new picture, but to its novelty as an unexpected visual configuration. In Potter's (1976) experiments, the conceptual masking hypothesis was put forth based on comparisons between conditions of rapid presentation of pictures and conditions in which brief pictures were followed by a single visual noise mask. Besides differing in terms of conceptual content, these items differ in terms of visual novelty and expectancy. That is, unlike a repeating picture or a repeating mask, each new picture provides the subject with an unpredictable new shape so that the changing-ISI sequence can be thought of as a stream of rapidly changing, novel visual events. To determine if it is the conceptual aspects of the new picture or simply its visual novelty that disrupts memory, it would be ideal to obtain two types of visual stimuli to present during the ISI that are equal with respect to visual attributes but differ with respect to conceptual content. Equating the sets for visual attributes would allow for a careful test of the visual novelty hypothesis by removing artifacts that might be introduced if the general visual appearance or complexity of the two sets differed. Two approaches are used in the present experiment to approximate this ideal set of stimuli.

One approach is to compare memory for the brief pictures under conditions in which the ISI contains normal pictures versus meaningless, nonsense pictures that share visual attributes with the normal pictures. In previous picture memory experiments the types of meaningless masks used have been noisy color masks (e.g. Potter,

1976) or jumbled scenes in which a picture is cut into equal sized pieces that are then rearranged (e.g. Hulme & Merikle, 1976). Neither type was suitable for the present experiment because the physical characteristics of a random noise mask differ greatly from the object-like characteristics of a picture, and jumbling a picture might leave too many recognizable, meaningful elements. The nonsense masks in the present experiment were made by tracing the basic shapes of the ISI-pictures but altering boundaries and coloration to disguise the picture's identity. Because they are meaningless versions of particular pictures, they will be referred to as nonsense pictures. The novel visual event hypothesis would be supported if new, nonsense pictures disrupt memory as much as new, meaningful pictures.

The other approach used to determine if it is the conceptual attributes of a new picture that disrupt memory was to present normally oriented ISI-pictures in one condition, and the same ISI-pictures upside down in the other condition. The rationale was that the visual attributes of the ISI-pictures would be virtually the same, but that conceptual information would be less accessible in the case of inverted pictures. If the concept is less accessible, then the inverted pictures would be expected to be less effective conceptual masks. If memory for the briefly glimpsed pictures is superior in the inverted-ISI condition, then the conceptual masking hypothesis would be supported. If the two conditions yield the same memory performance, this would not refute the conceptual masking hypothesis because both types of ISI-pictures contain conceptual information and the assumptions regarding inversion and conceptual accessibility may be incorrect.

Method

Subjects. Subjects were 40 male and 40 female undergraduates from University of Delaware who took part in the experiment to complete an optional course requirement. Subjects reported normal or corrected vision.

Materials. Thirty-two stimuli from the same pool used in Experiments 1 and 2 were used in the experimental sequences. One set of 16 pictures served as stimuli (brief pictures) in all 4 conditions. The remaining 16 served as ISI-pictures in the changing-ISI, and changing-inverted-ISI conditions. The repeating-ISI sequence used one of the two pictures employed in Experiment 1 to fill the ISI. The nonsense pictures were made with reference to the 16 ISI pictures. As described previously, the pictures were cut out from magazines and photographed on a homogeneous gray background. The cutouts sometimes consisted of a object alone or an object along with some of its original background (e.g., sky or grass). The nonsense pictures were made by tracing the cutouts from 35 mm slides onto acetate. Tracing was accomplished with lumocolor pens. The basic size and global shapes of the cutouts were copied, but boundaries and colors within the general shapes were altered so that the drawings were meaningless object-like configurations. The acetates were placed in slide mounts.

The 16 mm sequences were made by photographing the 35 mm slides of pictures and nonsense pictures using single frame photography. A gray filter was used when photographing the pseudopictures to approximate the gray background of the meaningful pictures.

Apparatus. A different laboratory was used than in the previous two experiments. A Visual Instrumentation variable speed 16 mm projector was used to rear project sequences into a room in which the subject was seated. Because rear projection was used projector noise was minimized. The experimenter was seated in the back of the same room and controlled the projector via a remote control box. Unlike the previous experiments, the recognition test was also photographed on 16 mm film and was presented by advancing the film one frame at a time. The visual angle subtended by the pictures was approximately $13^\circ \times 13^\circ$.

<u>Design and procedure</u>. The four experimental condtions were: repeating-ISI, changing-ISI, changing-inverted-ISI, and changing-nonsense-ISI. There were 20 individually run subjects (10 male and 10 female) in each condition. The 16 stimulus pictures were presented for 100 msec each with a 1.5 sec ISI. In the repeating-ISI condition, the ISI contained a single picture that the subject was familiarized with prior to viewing the sequence. In the changing-ISI and changing-inverted-ISI conditions the 16 ISI-pictures were presented in the same order but were inverted in the latter condition. In the nonsense-ISI condition, the nonsense pictures were presented during the ISI in the same order and orientation as the normal ISI-pictures they were based upon.

Subjects were informed that the purpose of the experiment was to study attention and memory. They were instructed to focus attention on the briefly presented pictures, trying not to allow the ISI-pictures to distract them. All subjects received a 5-item sample sequence and recognition test to familiarize them with the task. Following this, subjects were told that they would receive additional practice in focusing attention. Subjects in all conditions except the repeating-ISI condition were again presented with the sample sequence. At this point, subjects in the repeating-ISI condition were presented with the monitoring task.

In the monitoring task, subjects were provided with a target picture to hold in memory while viewing the same 16 ISI-pictures used in the changing-ISI condition, presented for 1.5 sec each in a continuous sequence. Subjects were instructed to respond as soon as the target (presented for 110 msec) appeared on the scene, trying not to allow the long pictures to distract them. In all conditions, following the practice task, subjects were presented with the experimental sequence and recognition test. The test and procedure were the same as in Experiments 1 and 2 except that in addition to "yes" and "no" responses, subjects were instructed to provide a confidence rating of sure or not sure.

Results and Discussion

The results provide strong support for the conceptual masking hypothesis. The mean proportion of brief pictures recognized (corrected for guessing), the mean proportion of hits, the mean proportion of false alarms, and the mean confidence ratings for hits and false alarms in each of the four ISI conditions is presented in Table 3.

Insert Table 3 about here

Because the changing-ISI condition is the control condition for each of the other three, three *a priori* comparisons were conducted.

Contrary to the hypothesis that number of pictures caused the poor performance in the changing-ISI condition (Experiment 1), in the present experiment, the repeating-ISI condition (with the monitoring task) still yielded significantly superior memory performance than that obtained in the changing-ISI condition, F (1,76) = 14.00, $p<.001$, MSe for all the comparisons = .02. Apparently it is not the presentation of numerous to-be-ignored pictures per se that reduces recognition memory for the brief pictures in the changing-ISI sequence, but the placement of the to-be-ignored pictures within the sequence. What disrupts memory for the brief pictures in the changing-ISI condition may be the conceptual identification processes elicited by new, unexpected pictures. The repeating picture apparently does not elicit the same processes or the same amount of processing as a new picture. Although the nature of the difference cannot be determined from these data, two possible explanations are: (a) the repeating picture can be conceptually identified much more rapidly than a new picture or (b) because it has already been conceptually identified, it need not undergo any conceptual processing but need only be recognized as it reappears (perhaps based on a match with a representation held in the subject's working memory).

Comparison of the changing-ISI condition with the nonsense-ISI and inverted-ISI conditions suggests that the disruptive effect of the ISI pictures is not due to their novelty as visual events, but to their conceptual attributes. Presentation of a new nonsense picture during the ISI yielded significantly better memory performance than presentation of a new, meaningful picture, $\underline{F}$ (1,76) = 9.00, $p<.005$. In fact, performance in the nonsense-ISI condition was quite similar to that obtained in the repeating-ISI condition. Although more pictures were remembered in the inverted condition than in the changing-ISI condition, this difference did not reach significance, $\underline{F}$ (1,76) = 3.5, $p<.10$. As mentioned previously, since both inverted and upright pictures contain conceptual information, a finding of no difference would not refute the conceptual masking hypothesis because assumptions regarding the effect of inversion on concept availability are speculative. The direction of the effect is encouraging, however, and future research might explore this issue by following each stimulus with an inverted or normal ISI- picture of brief duration (i.e., confined to the initial part of the ISI). By decreasing duration, the effect of inversion on concept availability may be increased, and inverted pictures might then prove to be significantly less effective conceptual masks.

Confidence ratings (see Table 3) showed that although fewer pictures were recognized in the changing-ISI condition, when subjects did recognize old items they expressed as much confidence in their decision as subjects in the other conditions. The average rating in each of the four conditions was 1.9 (2.0 would be the highest mean possible) showing that subjects were very confident when they responded "yes" to an old picture. The lower ratings obtained for false alarms suggest that subjects were equivocal about those "yes" responses.

General Discussion

Potter (1976) proposed that encoding of each briefly glimpsed picture in a sequence is terminated by the onset of the next new meaningful picture because of the elicitation of cognitive processes associated with extraction of the new picture's concept. This process, referred to as conceptual masking, was held to be the cause of the poor recognition memory performance that is obtained following rapid continuous presentation of pictures (e.g. Intraub, 1980; Potter & Levy, 1969). Experiments 1-3 support some aspects of the proposed process but at the same time suggest modification of the original formulation.

Experiments 1 and 3 support the hypothesis that the interference referred to by Potter is indeed conceptual in nature. Experiment 1 showed that memory for briefly glimpsed pictures is disrupted when a new picture, as opposed to a familiar, repeating picture, is presented during the ISI. Experiment 3 showed that the inferior performance obtained when a new picture appears in the ISI is not due to the greater number of pictures viewed by subjects in that condition. When the number of to-be-remembered and to-be-ignored pictures was equated, memory was still superior when a familiar picture repeated during the ISI. Experiment 3 demonstrated that the disruptive effect of a new picture in the ISI cannot be attributed to its visual novelty or unexpectedness. Nonsense pictures, created by tracing and distorting each ISI picture, were presented during the ISI and did not disrupt memory as much as the meaningful pictures they had been copied from, although like the meaningful pictures they were novel, object-like visual configurations. Memory performance in the nonsense picture condition was, in fact, quite similar to that obtained in the repeating-ISI condition. Inverting the ISI picture did not significantly enhance memory for the brief stimuli, but the direction of the results suggests that inverting a picture may reduce the accessibility of conceptual information, thus creating a less effective conceptual mask while holding visual characteristics virtually constant. Additional research to explore this possibility was discussed in Experiment 3.

Although the masking discussed by Potter (1976) seems to be conceptual in nature, its role in rapid continuous presentation of pictures, and by extension, in visual scanning is probably different than the initial formulation suggested. According to that formulation, once a picture has been identified (which it was estimated occurs within about 100 msec), additional processing is required to encode the newly identified picture into memory. Potter (1976) proposed that the newly identified picture is held in a short-term conceptual store for a few hundred milliseconds during which time it is vulnerable to conceptual masking. Because the store can hold only one scene at a time, conceptual identification of a new picture terminates encoding of the picture currently held in the store. For this reason Potter suggested that in visual scanning the average fixation frequency of three per second represents a compromise between the need for rapid identification of the environment and the need for an uninterrupted interval to allow the observer to store some portion of what has been seen.

The present research suggests some changes in this view of the conceptual short-term store and conceptual masking. Experiments 1 and 3 show that althought presentation of a new ISI picture was more disruptive than presentation of a familiar, repeating picture or a nonsense picture during the ISI (presumably because of the conceptual processing it elicits) memory for the brief pictures was still relatively good with 63% and 73% remembered in the two experiments, respectively. Memory did not approach the low level obtained following rapid continuous presentation. This indicates that encoding of a briefly glimpsed picture can proceed in spite of the onset of a new, meaningful visual event. Presentation of a subsequent picture alone is not sufficient to terminate encoding (see also, Erdelyi & Blumenthal, 1973). Consistent with this observation is recent research in which 24 briefly shown pictures were presented in a sequence in which a blank interval was presented after each picture or after each group of two, three, or four pictures. The effect these groupings had on recognition memory suggested that the very short-term buffer associated with rapid serial visual presentation of pictures or words (see Forster, 1975; Potter, 1976) may hold up to three complex visual scenes concurrently (Intraub & Nicklos, note 1). Encoding of a briefly glimpsed picture apparently is not limited to the time between its onset and onset of the new picture.

Selective attention instructions and picture memory

In addition to this point, Experiment 2 shows that to a large degree the observer can voluntarily control the extent to which encoding will proceed for particular pictures in a sequence. In that experiment, although subjects viewed the same experimental sequence, memory for the 16 brief pictures increased from 12% remembered to 54% and 63% remembered, as attention instruction changed emphasis from the long pictures, to all pictures, and to the brief pictures, respectively (first recognition test, corrected for guessing). The effect of attention instruction on memory was not limited to the briefly presented pictures. The high level of recognition memory usually obtained with pictures having durations of one second or more (e.g., Standing, 1973) decreased dramatically from 89% to 54% remembered as attention instructions shifted focus away from the long pictures to the brief pictures. The same pattern of results was obtained in the subjects' secondary recognition test. Simply watching pictures does not insure good recognition memory. This is consistent with other research on the effects of intentional strategy on pictorial encoding (Graefe & Watkins, 1980; Weaver & Stanny, 1978) and extends this effect to conditions using continuous pictorial presentation as well as brief pictorial presentation. The results are also similar to those obtained using auditorily presented sequences of alphanumeric stimuli (Hamilton & Hockey, 1974).

Conclusion

The present research indicates that while presentation of a new meaningful visual input disrupts encoding of briefly glimpsed pictures, it does not necessarily terminate encoding. Contrary to the initial formulation of the conceptual masking hypothesis, it is unlikely that each picture in a rapid continuous sequence abrupty interrupts processing of the picture that precedes it. Instead, by drawing attention away from the previous picture it interferes with ongoing encoding or rehearsal processes. The question of automaticity in relation to the disruptive effects of new meaningful visual events still remains open. In the present experiments, subjects received only minimal practice viewing the sequences and were presented with a single experimental sequence. Clearly under these conditions subjects seemed unable to disattend new meaningful inputs. Whether or not highly trained subjects would be able to increase their recognition memory performance in a changing-ISI condition to match that obtained in conditions where the ISI contains a repeating picture or a new nonsense picture is a question to be addressed in furture research.

Reference Notes

1. Intraub, H. & Nicklos, S. The capacity of short-term memory for successively presented pictures. Paper presented at the 89th Annual Convention of the American Psychological Association, Los Angeles, California, 1981.

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Footnotes

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[1]The formula used to correct for guessing was Y = (TY-FY)/(1-FY) in which Y is the corrected proportion of yes responses, TY is the proportion of yes responses to old pictures, and F-Y is the proportion of yes responses to distractors. It should be noted that reliable d' scores cannot be obtained from these data because of the relatively small number of trails (16 targets and 16 distractors) and the fact that with these stimuli many subjects make no false alarms. Group d' scores, however, which can be calculated from these data (see tables for the proportion of false alarms and raw hits in each condition), yield the same pattern of results as the guessing corrected scores.

[2]Experiments 1 and 2 were run simultaneously so that the "attend to brief" condition reported in Experiment 2 (in which brief pictures were tested in the primary recognition test) refers to the same set of data as the changing-ISI "attend to brief" condition reported in Experiment 1.

Table 1

The mean proportion of pictures recognized ($\bar{X}$), the mean proportion of false alarms (FA), and the mean proportion of pictures corrected for guessing ($\bar{X}_c$) in the three ISI conditions

ISI Condition	$\bar{X}$	FA	$\bar{X}_c$
Blank	.89	.02	.89 (.14)
Repeating	.82	.08	.80 (.14)
Changing	.64	.05	.63 (.13)

Note. Numbers in parentheses are standard deviations.

Table 2

The mean proportion of pictures recognized ($\bar{X}$) and the mean proportion of false alarms (FA) for brief and long pictures for each attention instruction in the first and second recognition tests

	Pictures to which the subject is instructed to attend					
	Brief pictures		All Pictures		Long pictures	
Type of Picture	$\bar{X}$	FA	$\bar{X}$	FA	$\bar{X}$	FA
			First recognition test			
Brief	.64	.05	.62	.15	.15	.06
Long	.58	.07	.76	.08	.88	.02
			Second recognition test			
Brief	.60	.05	.40	.03	.28	.12
Long	.49	.01	.68	.10	.91	.02

Note. Recognitions scores corrected for guessing are in Figures 1 and 2.

Table 3

The mean proportion of pictures recognized ($\bar{X}$), and mean confidence ratings ($\bar{X}_{conf}$) proportion of false alarms (FA), and mean confidence ratings (FA_{conf}) proportion of pictures recognized corrected for guessing ($\bar{X}_c$) in each ISI condition

ISI Condition (Type of picture)	$\bar{X}$	$\bar{X}_{conf}$[a]	FA	FA_{conf}[a]	$\bar{X}_c$
Changing	.75	1.9	.07	1.3	.73 (.21)
Repeating	.90	1.9	.05	1.2	.90 (.08)
Nonsense	.88	1.9	.07	1.6	.87 (.11)
Inverted	.84	1.9	.11	1.3	.82 (.14)

[a]Confidence ratings of "sure" and "not sure" were coded as 2 and 1, respectively.

Note. Numbers in parentheses are standard deviations.

Figure Captions

Figure 1. Proportion of long and brief pictures recognized (corrected for guessing) following each attention instruction in the first recognition test.

Figure 2. Proportion of long and brief pictures recognized (corrected for guessing) following each attention instruction in the second recognition test.

Figure 1

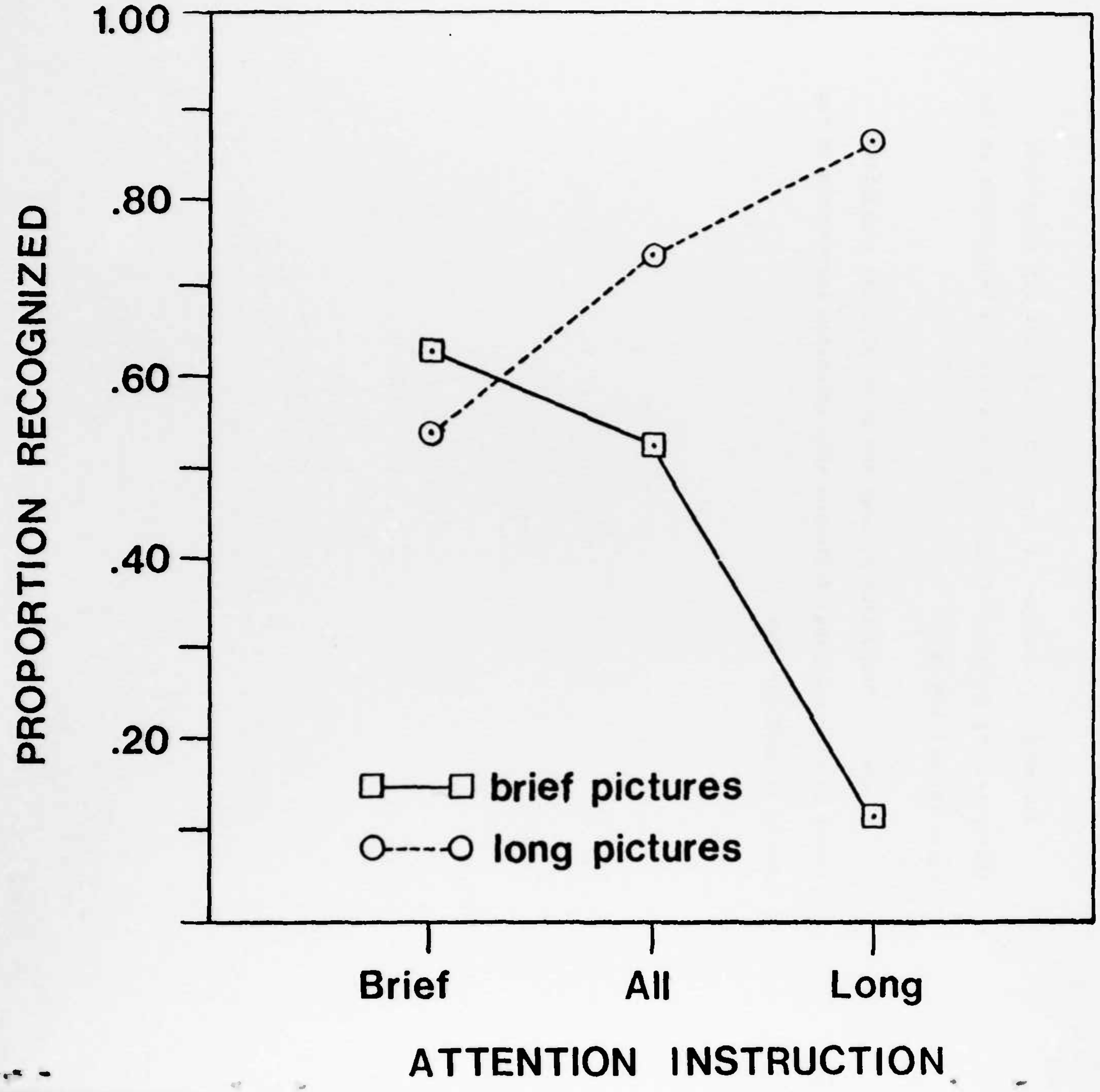
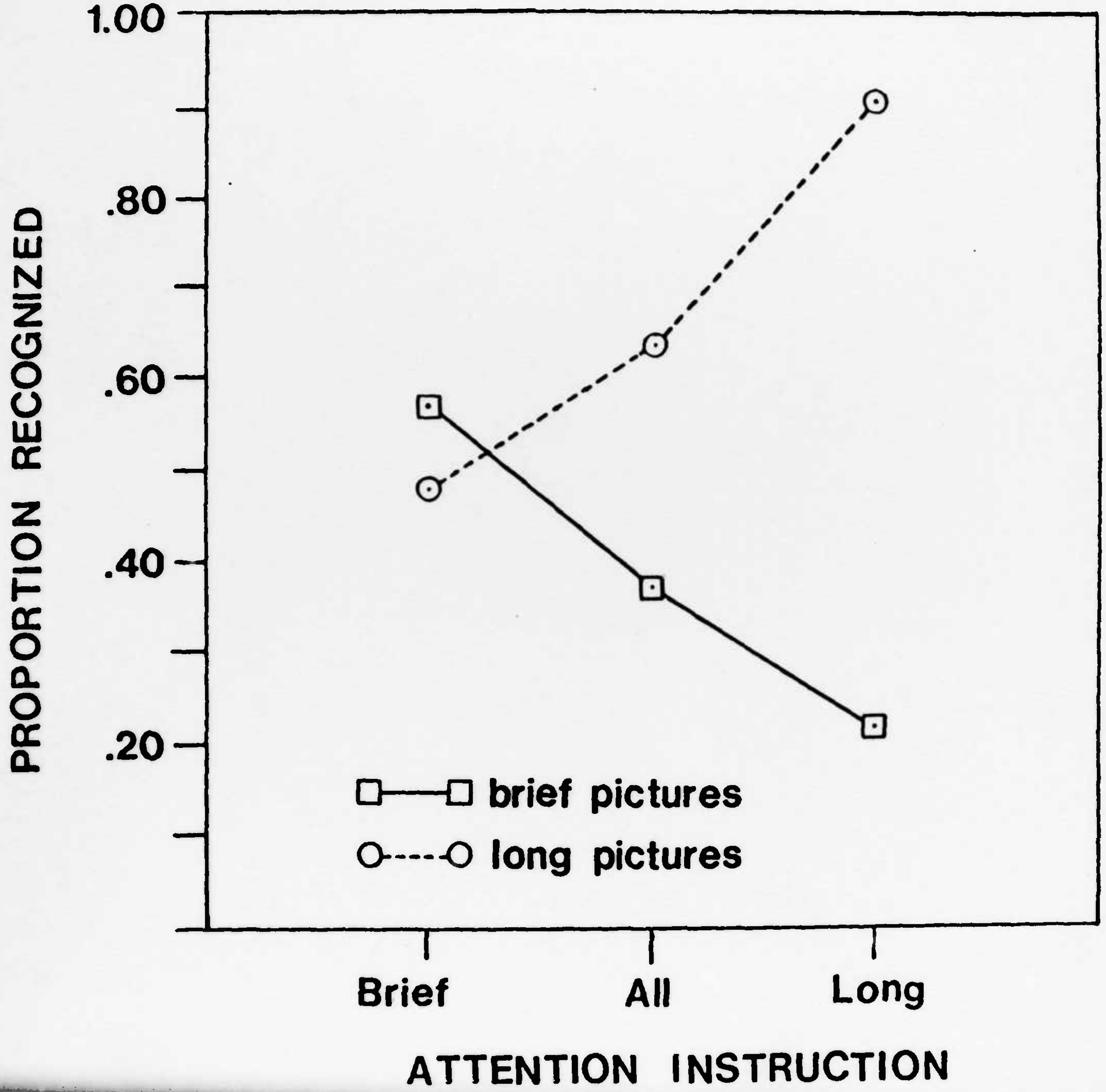

1.00
.80
.60
.40
.20
PROPORTION RECOGNIZED
brief pictures
long pictures
Brief
All
Long
ATTENTION INSTRUCTION

Figure 2


1.00
.80
.60
.40
.20
PROPORTION RECOGNIZED
brief pictures
long pictures
Brief
All
Long
ATTENTION INSTRUCTION