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How Much Is an Icon Worth?

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We report a new technique for assessing the amount of information extracted from the icon[1] that follows a briefly presented picture. The problem of how to measure such information was formulated in terms of how much physical exposure of a picture an icon is worth. Consider two types of stimulus presentations, each with a base duration of d ms. The first is a d-ms picture followed by an icon, and the second is a $d + a$-ms picture not followed by an icon. How large does a have to be so that equivalent amounts of information are extracted in the two cases? To answer this question, we showed people pictures and later tested their memory for the pictures. We found that the physical exposure duration needed to reach a particular level of performance was approximately 100 ms longer when an icon was not permitted versus when the icon was permitted. This value was independent of the base duration and the luminance of the picture. Moreover, the same value was obtained using three different kinds of memory test and four different sets of pictures. We conclude that an icon is worth approximately 100 ms of additional physical exposure duration. A reasonable explanation for this robust equivalence between icon and stimulus is that the same encoding processes are responsible for extracting information from the icon and from the physical stimulus. Therefore, any variable that affects these encoding processes must affect extraction of information from the icon and the physical stimulus in an identical manner. This prediction was confirmed for one such variable, picture luminance.

When a visual stimulus is presented and then followed by darkness, information can be extracted from the iconic image (icon) that follows (Neisser, 1967; Sperling, 1960). When one views such a stimulus, there is no subjective dividing line that separates the offset of the physical stimulus from the onset of the icon. Indeed, naive observers think that an icon is an extension of the physical stimulus. They speculate, for example, that the projector bulb or the cathode-ray tube phosphor that displays the stimulus must extinguish relatively slowly after it is turned

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[1] The term *icon* has been used in two different ways. Sometimes it refers to an image that is formed immediately at the time of stimulus onset and continues after stimulus offset. Other times it refers *only* to the image that follows stimulus offset. In this article, it will be used in the latter sense.

off. This powerful subjective experience led us to hypothesize that the information extracted from the icon might be parsimoniously characterized in terms of the information that could be extracted from a physical extension of the stimulus.

We assess here the viability of this hypothesis. In each of four experiments, complex, naturalistic pictures were presented for varying exposure durations. Each picture was followed either by an immediate noise mask or by a noise mask that was delayed 300 ms. Subsequently, memory for the pictures was tested. Because an icon is permitted with a delayed mask (Loftus & Ginn, 1984) but not with an immediate mask (Sperling, 1963; Turvey, 1973), performance differences between these two conditions reflect information extracted from the icon.

To derive a measure of the icon's worth, we reason as follows. Suppose a picture is presented for a base duration of d ms. If the picture is followed by an icon, then when it is later tested, it will show some performance level that we term $p(d, i)$. Alternatively, if the picture is followed by a ms of additional physical exposure duration but no icon, then it will show a performance level that we term $p(d + a, \bar{i})$. The worth of the icon may now be characterized as the value of a required so that $p(d,i) = p(d + a, \bar{i})$.

Experiment 1

An *old/new* recognition procedure was used in Experiment 1. In an initial study phase, target pictures were presented, one by one, for inspection. Immediately following the study phase was a test phase in which the target pictures, randomly intermingled with distractor pictures, were presented, again one by one, in an *old/new* recognition memory test. Two independent variables were combined in the study phase. The first was exposure duration, which varied from 62 to 1,300 ms, and the second was the presence or absence of a noise mask following the picture's offset. In the immediate-mask conditions, the mask immediately followed the picture's offset. In the delayed-mask conditions, the mask was delayed by 300 ms following the picture's offset. In the control conditions, no mask was presented. The control conditions were ancillary to the major purpose of the experiment and were included to resolve an apparent discrepancy in the literature. Loftus and Ginn (1984) found that picture memory performance in an immediate-mask condition was poorer than performance in a no-mask control condition. Intraub (1980, Experiment 1), in contrast, found that performance in an immediate-mask condition did not differ significantly from performance in a no-mask control condition.

Table 1
Stimulus Luminances (Millilamberts)

Stimulus	Luminance
Adapting field	0.07
Projector on, no slide	38.43
Fixation spot	0.38
Pattern mask	
Bright background	25.19
Black markings	2.57
Gray markings	2.89

Method

Subjects. One hundred eighty University of Washington undergraduates participated for course credit. They were run in 36 groups of 5 subjects per group.

Stimuli. The targets were 144 naturalistic color pictures, prepared as 35-mm slides, depicting seascapes, landscapes, and cityscapes. They were randomly placed into two slide trays of 72 slides per tray.

The noise mask consisted of a jumble of straight and curved, black and gray lines on a white background. The relevant luminances of target and mask were such that when the mask was displayed concurrently with a target picture, the target could not be seen at all. The same mask was used in all four experiments.

Apparatus. The target pictures were displayed by a Kodak random access carousel projector and subtended a visual angle that ranged from 15° to 22° horizontal and from 10° to 15° vertical, depending on where the subject sat. Two additional Kodak standard projectors were used to display the mask and a dim fixation point that occurred just prior to each target. Timing of all stimuli was controlled by Gerbrands tachistoscopic shutters with rise and fall times of approximately 1 ms. All relevant luminances are shown in Table 1.

Design. There were three levels of mask condition: immediate mask, delayed mask, and no mask. Within each mask condition there were six levels of exposure duration, as indicated in Table 2, for a total of 18 experimental conditions. The design was not completely factorial, because the exposure durations in the immediate-mask conditions were longer than those in the delayed- and no-mask conditions.

Procedure. An experimental session consisted of a study phase followed by a test phase using the pictures in the first slide tray and then another study and test phase using the pictures in the second slide tray. For each tray, 36 pictures were presented at the time of study. The

Table 2
Exposure Durations (ms) for Experiment 1

Masking condition		
No mask	Delayed mask	Immediate mask
62	62	320
270	270	525
320	320	575
350	350	620
620	620	880
1,050	1,050	1,300

18 study conditions occurred in random order with the restriction that each condition occur once during the first 18 study trials and once during the second 18 study trials.

The sequence of events on each study trial was as follows. First, a 300-ms tone signaled the subjects to fixate a dim spot that concurrently appeared at the center of the viewing field. A picture was then presented, followed by either a 300-ms mask (in the immediate-mask conditions) or 300 ms of darkness followed by a 300-ms mask (in the delayed-mask conditions) or simply darkness (in the no-mask, control conditions). An intertrial interval of 8 s was followed by the warning tone signaling the start of the next trial.

At the time of test, all 72 pictures in the slide tray were shown in a random order for 6 s apiece. The test order was different for the two slide trays, but for each tray the order was identical over all 36 groups in the experiment. For each test picture, the subject was asked to respond yes or no corresponding to whether he or she judged the picture to have occurred during the study phase.

Each of the 144 pictures appeared as a target for 18 of the 36 groups and as a distractor for the remaining 18 groups. Each picture occurred once in each of the 18 study conditions over the 18 groups for which it appeared as a target.

Results

Because all study conditions were intermixed within the study phase, there was only a single false-alarm rate, which was 0.165. Thus, all hit rates are directly comparable to one another. Figure 1 (top panel) shows hit rate as a function of exposure duration for each of the three mask conditions. There are several noteworthy aspects of these data. First, in agreement with past experiments (e.g., Loftus & Bell, 1975; Loftus & Kallman, 1978; Potter & Levy, 1969), performance in all three mask conditions increased with exposure duration. Second, performance in the no-mask control condition was higher than performance in the delayed-mask condition, which, in turn, was higher than performance in the immediate-mask condition.

Intraub (1980, Experiment 1) found no difference between a no-mask and an immediate mask condition. We did. As is evident, however, the difference between the immediate- and no-mask curves is smaller at long exposure durations, where absolute performance level is at about the same as it was in Intraub's experiment.

The difference between the delayed-mask and no-mask conditions replicates a finding reported by Loftus and Ginn (1984) and indicates that a noise mask disrupts memory performance even at 300 ms following stimulus offset. Loftus and Ginn present evidence that the picture's icon has vanished by 300 ms; thus the delayed mask must disrupt some process other than extraction of information from the icon. This point will be elaborated below.

We are primarily interested in the difference between the immediate- and delayed-mask conditions, which reflects information extracted from the icon. Qualitatively, our results replicate those of Hulme and Merikle (1976), who found an effect of mask delay

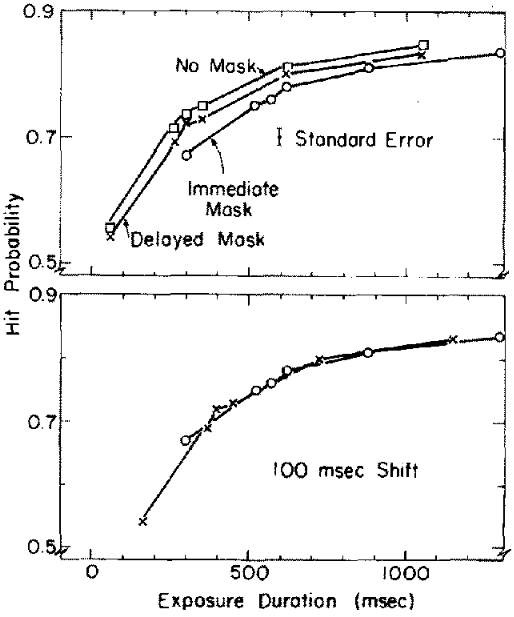

Figure 1. Experiment 1: Recognition memory (hit probability) as a function of stimulus exposure duration. (The top panel shows all mask conditions on the same axes. The bottom panel shows the delayed-mask and immediate-mask conditions only, and the delayed-mask curve has been displaced 100 ms to the right. Each data point is based on 720 observations.)

on recognition memory that diminished with increasing target exposure durations. As noted earlier, however, our goal is to obtain a quantitative characterization of the icon in terms of how much additional physical exposure duration it is worth. Consider, for example, a picture presented for a base duration, *d*, of 270 ms. If such a picture is followed by an icon (delayed-mask conditions), then the resulting hit rate is roughly 0.69. However, if a picture is not permitted an icon (immediate-mask conditions), it requires approximately 370 ms of exposure duration to achieve this same hit rate. Having an icon following a 270-ms picture is therefore equivalent (at least in terms of subsequent recognition memory performance) to having an additional 370 − 270 = 100 ms of what we term additional physical exposure duration. This is the icon's worth.

Because an icon's worth is represented graphically by the horizontal difference between the immediate- and delayed-mask curves in the top panel of Figure 1, we can assess the effect on it of base stimulus duration by performing a lateral translation of one of these curves relative to the other. The bottom panel of Figure 1 shows that when the delayed-mask curve is shifted 100 ms to the right, it coincides quite well with the immediate-mask curve. The major results of Experiment 1 can thus be summarized as follows. First, for extracting information used in a recognition test, having an icon is equivalent to having approximately 100 ms of additional physical exposure duration. Second, this value of 100 ms is independent of the picture's base exposure duration. Note that these results must logically hold not only for the particular dependent variable—hit rate—that we have used in this experiment but also for any other dependent variable (e.g., d') or any hypothetical construct (e.g., amount of extracted information) that is a monotone transformation of hit rate.

Discussion

Viewing a picture leads to a memory representation that can be conceptualized as a set of information about the picture. Some subset of that information is used as the basis for responding in an *old/new* recognition test. One explanation for the results of Experiment 1 is that an icon is equivalent to an additional 100 ms of physical exposure duration at least in terms of that subset. A stronger explanation is that the memory representation that accrues from a *d*-ms picture followed by an icon is identical *in all respects* to the memory representation that accrues from a $d + 100$-ms picture without an icon. If this second explanation is correct, then an icon should be worth 100 ms of additional physical exposure duration no matter what subset of the memory representation is tapped. Experiments 2 through 4 assessed this possibility by testing pictures in different ways that presumably tap different subsets of memorial information.

Experiment 2

In Experiment 2, memory was tested in a paradigm described by Intraub (1980, Experiment 4) and by Loftus and Ginn (1984): Subjects were asked to report as many details as they could from a picture that they had just seen. This dependent variable was chosen for three reasons. First, as just indicated, we wanted to tap a different subset of memorial information than that required in a recognition test. Second, test-position effects, which are very strong in recognition memory experiments, do not come into play when each picture is tested immediately after it is presented. Third, number of reported details is both more sensitive than yes–no recognition and is simpler from a design standpoint (in that one does not have to counterbalance for target/distractor.) These methodological concerns are not trivial: Because the present data analysis technique requires a very accurate assessment of the shapes of different curves, a great deal of statistical power is needed.

Method

Subjects. Seventy-three University of Washington undergraduates participated for course credit. They were run in 12 groups of 4 to 9 subjects per group.

Stimuli. Sixty new pictures of cityscapes, landscapes, home interiors, and weddings were prepared as 35-mm slides. The primary criterion for inclusion of a given picture was that it contain a variety of identifiable, nameable details.

Apparatus. The apparatus was the same as in Experiment 1.

Design and procedure. As in Experiment 1, the two principal independent variables were exposure duration and mask condition. There were two levels of mask condition: immediate- and 300-ms delayed-mask. Six exposure durations—50, 100, 150, 200, 350, and 500 ms—were factorially combined with mask condition to produce 12 experimental conditions. Each of the 60 pictures occurred once in each of these 12 conditions over the 12 groups of subjects.

In an experimental session, the 60 pictures were presented one by one. The 12 experimental conditions occurred randomly over the 60 trials with the restriction that, within each block of 12 trials, each condition occur once. Each test trial consisted of the following sequence of events. First, a 1.5-s warning tone signaled the subjects to look at the fixation point. Next came the target picture. Finally, subjects had 20 s to write down as many details as they remembered from the target. They were instructed, "Write down as many details as you can so that a person looking at your list would be able to reproduce the picture as accurately as possible." Following the 20 s was the warning tone for the subsequent trial.

Following the experiment proper, subjects scored their own data. They were shown 60 pictures again, and for each picture they wrote down the number of correct details that they had originally listed. They were told that "a detail" should correspond to a single object listed from the picture. For example, the response "two people" should count as two details. In practice, there were very few cases in which responses were ambiguous. In such cases, subjects were told to use their own judgment.

Results and Discussion

Subjects had no difficulty carrying out the response task. Nonexistent details were written down in less than 5% of the trials. The responses almost invariably consisted of the names of objects (e.g., "a person in the middle" or "a boat in the upper left") rather than mere mention of some physical characteristic. An informal survey of the data indicated no qualitative differences in the sorts of details that were reported as a function of the various experimental conditions.

Figure 2 (left panel) shows the mean number of reported details as a function of exposure duration, with separate curves for the two mask conditions. As in Experiment 1, performance increased with increasing exposure duration, and performance in the delayed-mask conditions was superior to performance in the immediate-mask conditions. Intraub (1980, Experiment 4), using a similar paradigm, found no significant difference between a no-mask and an immediate-mask condition. The present finding of a substantial difference between the delayed-mask and immediate-mask conditions seems at odds with Intraub's result. However, the curves in Figure 2 converge at long exposure durations. If duration had been long enough to produce the absolute performance level obtained by Intraub (approximately 4.5 details), then the difference between the delayed- and immediate-mask conditions would probably have been minimal.

The icon as a source of information was assessed using the same technique as in Ex-

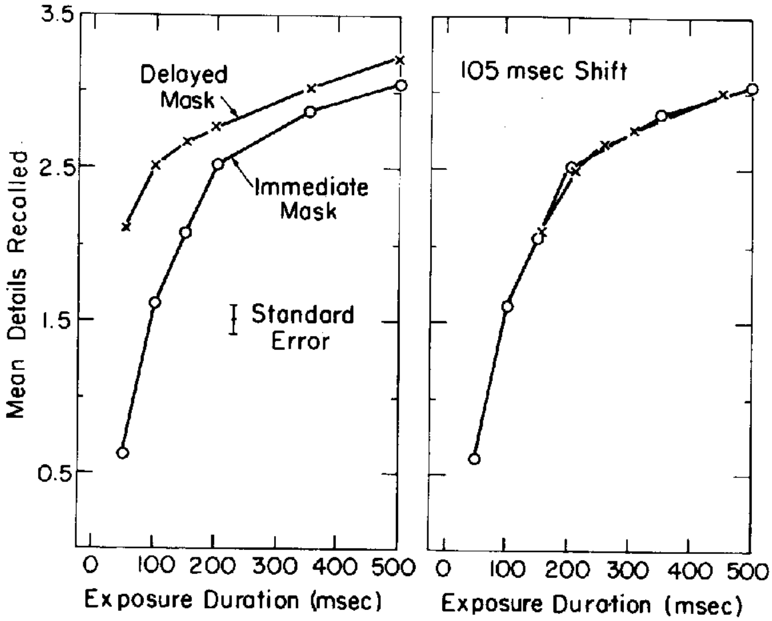

Figure 2. Experiment 2: Mean number of details reported as a function of stimulus exposure duration. (The left panel shows both mask conditions on the same axis. In the right panel, the delayed-mask curve is displaced to the right by 105 ms. Each data point is based on 365 observations.)

periment 1. The right panel of Figure 2 shows that when the delayed-mask curve is shifted 105 ms to the right, it coincides perfectly with the immediate-mask curve. In Experiment 2, therefore, the best estimate of the equivalent additional exposure duration contributed by the icon is 105 ms, and again this value is independent of the base exposure duration of the picture.

In both Experiments 1 and 2, the performance curves are negatively accelerating. This means that at longer exposure durations, the assessment of horizontal differences between curves becomes increasingly less reliable. That is, a constant amount of vertical noise (e.g., the amount indicated by the standard error) implies an increasingly greater amount of horizontal noise as the curves become flatter. For this reason, the conclusion that the icon is worth 100 ms becomes more tentative for long exposure times (e.g., 300 ms or more).

Experiment 3

Experiment 3 was a replication of Experiment 2 except that a third dependent variable—subjective rating of how well a picture would be remembered—was used to probe the memory representations of the pictures. The rationale for this dependent variable was much the same as the rationale for using a new dependent variable in Experiment 2. First, we wanted to probe the memory representation using a variety of different dependent variables in order to test the hypothesis that the entire memory representation following a d-ms, delayed-mask presentation is equivalent to that following a $d + 100$ ms, immediate-mask presentation. Subjective rating is simply a dependent variable that is different from the previous two. Second, the use of subjective ratings is methodologically very simple. It permitted much more efficient data collection than was possible in Experiments 1 and 2.

Method

Subjects. Sixty-five University of Washington undergraduates participated for course credit. They were run in 10 groups of from 4 to 8 subjects per group.

Stimuli. A new set of 240 pictures, drawn from the same pool as the Experiment 1 pictures, was used in Experiment 3. Eighty of these pictures were used for practice, and the other 160 were used in the actual experiment.

Table 3
Exposure Durations (ms) for Experiment 3

Masking condition	
Delayed mask	Immediate mask
30	130
60	160
90	190
120	220
150	250

Apparatus. The apparatus was the same used in Experiments 1 and 2 except that (a) all timing and response collection was controlled by an Apple II computer, and (b) all projection apparatus was enclosed in a soundproof box.

Design and procedure. Pictures were followed by either an immediate or a 300-ms delayed mask. There were five values of exposure duration within each of the two mask conditions, as shown in Table 3, for a total of 10 conditions. Note that each immediate-mask duration is 100 ms greater than the corresponding delayed-mask duration. This arrangement reflected our desire to compare immediate- and delayed-mask conditions across equal performance ranges, along with our expectation that an icon would be worth approximately 100 ms.

Each of the 160 test pictures was shown in each of the 10 conditions across the 10 groups of subjects.

At the start of a session, the experimenter explained to the subjects what an *old/new* recognition test was. She then explained that their task would be to rate each of a series of pictures, on a scale from 1 to 5, as to how well they would later be able to recognize it. Following these instructions, subjects saw but did not rate 40 practice pictures—4 in each of the 10 experimental conditions. They then saw and rated 20 more practice pictures, 2 in each of the 10 conditions. If any subject wanted more practice, then all subjects saw and rated 20 more practice pictures.

When all subjects were comfortable with the task, the experiment proper began. Subjects saw a series of 160 target pictures and rated each one. The 10 experimental conditions occurred in random order with the restriction that within each block of 20 trials, each condition occur twice. On each trial, the following series of events occurred. First, a 1-s tone and a simultaneous fixation point signaled the start of a trial. Next, the target picture was displayed. One s after the offset of the mask, a beep was sounded, signaling that the just-presented picture should now be rated. Each subject entered a rating from 1 (*definitely would not remember the picture*) to 5 (*definitely would remember the picture*) into a response box on his or her desk. After all subjects had entered their responses, there was a $\frac{1}{2}$-s delay, followed by the signaling tone for the next trial.

Results and Discussion

The middle left panel of Figure 3 shows mean rating as a function of exposure duration, with separate curves for the immediate- and delayed-mask conditions. In the middle right panel, the delayed-mask curve has been shifted to the right by 110 ms and overlaps almost perfectly with the immediate-mask curve.

Subjects reported that their rating of an individual picture was determined more by the idiosyncratic characteristics of the picture than by the experimental condition in which the picture was presented. Accordingly, we computed a mean rating over all 10 groups for each of the 160 pictures. There was indeed substantial interpicture variation. The highest rating (awarded to a picture of a sunset over sailboats) was 4.47. The lowest rating, 2.23, went to an overexposed shopping center. Means for the 10 experimental conditions were computed separately for the lowest rated 60 pictures and the highest rated 60 pictures. These data are shown in the bottom and top panels of Figure 3. For both high- and low-rated pictures, the horizontal separation between the immediate- and delayed-mask curves is 110 ms. Evidently, the worth of a picture's icon is not affected by the picture's rated recognizability.

Experiment 4

Experiments 1–3 suggest that the information extracted from an icon is equivalent to the information extracted from a 100-ms extension of the physical stimulus. One hy-

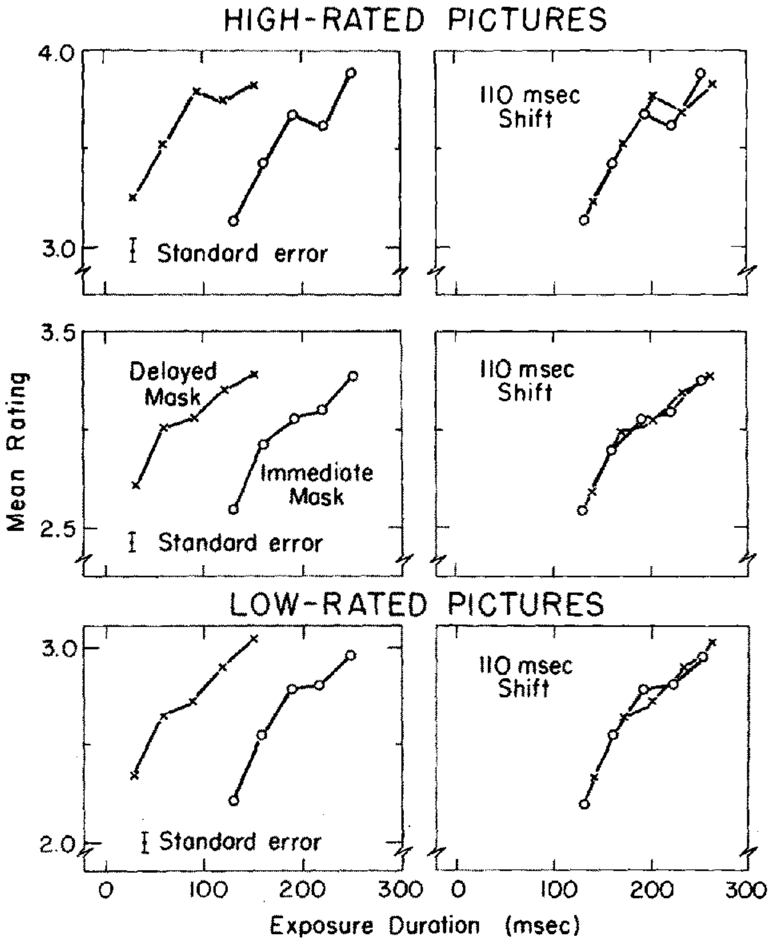

Figure 3. Experiment 3: Mean recognizability ratings as functions of stimulus exposure duration. (The middle panels show unconditional data; the top panels show data from the 60 highest rated pictures; and the lower panels show data from the 60 lowest rated pictures. In the right-hand panels, the delayed-mask curves are displaced to the right by 110 ms. Each middle-panel data point is based on 1,008 observations. Each top- and lower-panel data point is based on 378 observations.)

pothesis to explain this result is that the encoding mechanisms that extract information from the icon are the same as those that extract information from the physical stimulus. If this hypothesis is correct, then any variable affecting information extraction from the physical stimulus must similarly affect information extraction from the icon.

One variable that affects information extraction from the stimulus is luminance. Loftus (1982, in press) has shown that high-luminance pictures are remembered better than low-luminance pictures in both a recognition and a detail-recall test. Experiment 4 was essentially a replication of Experiment 3, with stimilus luminance as an additional factor. The logic of Experiment 4 was this. The pictures of Experiments 1-3 were shown in a high-luminance (bright) condition, and the icon was found to be worth 100 ms of additional physical exposure. Suppose that memory of an immediate-masked picture is, as expected, poorer in a low-luminance (dim) condition, reflecting less efficient extraction of information from the physical stimulus. If the same encoding mechanisms continue to operate during the icon, then information extraction from the icon will be similarly less efficient, but in a very specific way: The information extracted from the icon of a dim picture must still be equivalent to the information extracted from an additional 100 ms of the dim picture itself. In other words, the worth of an icon must be independent of stimulus luminance.

Alternatively, if the encoding mechanisms operating during the icon are different from those operating during the physical stimulus, then such independence would not occur unless by coincidence. Suppose, for example, that luminance, while affecting extraction of information from the stimulus, did not affect extraction of information from the icon. In this event, information extracted from the icon, though unaffected by luminance in an *absolute* sense, would increase for dim pictures when measured by additional physical stimulus duration.

Method

Subjects. Ninety-six University of Washington undergraduates participated in exchange for course credit. They were run in 20 groups of 4 to 8 subjects per group.

Stimuli. The same stimuli used in Experiment 3 were used in Experiment 4.

Table 4
Exposure Durations (ms) for Experiment 4

Masking condition	
Delayed mask	Immediate mask
30	140
60	170
90	200
120	230
150	260

Apparatus. The same apparatus used in Experiment 3 was used in Experiment 4. A filter wheel, also under computer control, was used to vary target luminance on a trial-to-trial basis.

Design and procedure. The design was the same as that of Experiment 3 except that target pictures were shown at one of two luminance levels. Bright pictures were shown at the same luminance level used in Experiments 1-3. Dim pictures were attenuated by 2.0 log units using a neutral-density filter. Luminance level was factorially combined with both mask delay and stimulus duration. There were five levels of stimulus duration within the immediate- and delayed-mask conditions as shown in Table 4. This resulted in a total of 20 conditions, which were presented in a random order over the 160 trials of the experiment, with the restriction that each condition be shown twice in each block of 40 trials. The procedure was identical to that used in Experiment 3.

Results

Mean rating as a function of exposure duration is shown in Figure 4. Data for dim and bright pictures are shown in the top and bottom panels, respectively. As in Figure 3, the right panels show the delayed-mask curves shifted horizontally so as to provide the best overlap with the immediate-mask curves.

The data are clear. First, information is extracted more efficiently from the bright pictures than from the dim pictures, at least as indicated by the subjective ratings. This finding replicates those of Loftus (1982, in press), who found memory performance, as measured by recognition and detail-recall tests, to be similarly affected by an identical luminance manipulation. Second, the worth of an icon is identical—110 ms—for bright and dim pictures.

Discussion

The effect of luminance on extraction of information from the icon has been examined previously in a Sperling (1960) partial-report paradigm. Adelson and Jonides (1980) found very little effect of luminance, whereas Keele and Chase (1967) and Long and Beaton (1982) both found better performance with higher luminances. The differences are probably attributable to different luminance levels used in the different experiments. In any event, the present results indicate, in agreement with Keele and Chase (1967) and Long and Beaton (1982), that, in an absolute sense, less information is extracted from the icon of a dim picture than from the icon of a bright picture. Both are worth 110 ms of additional physical exposure duration, but

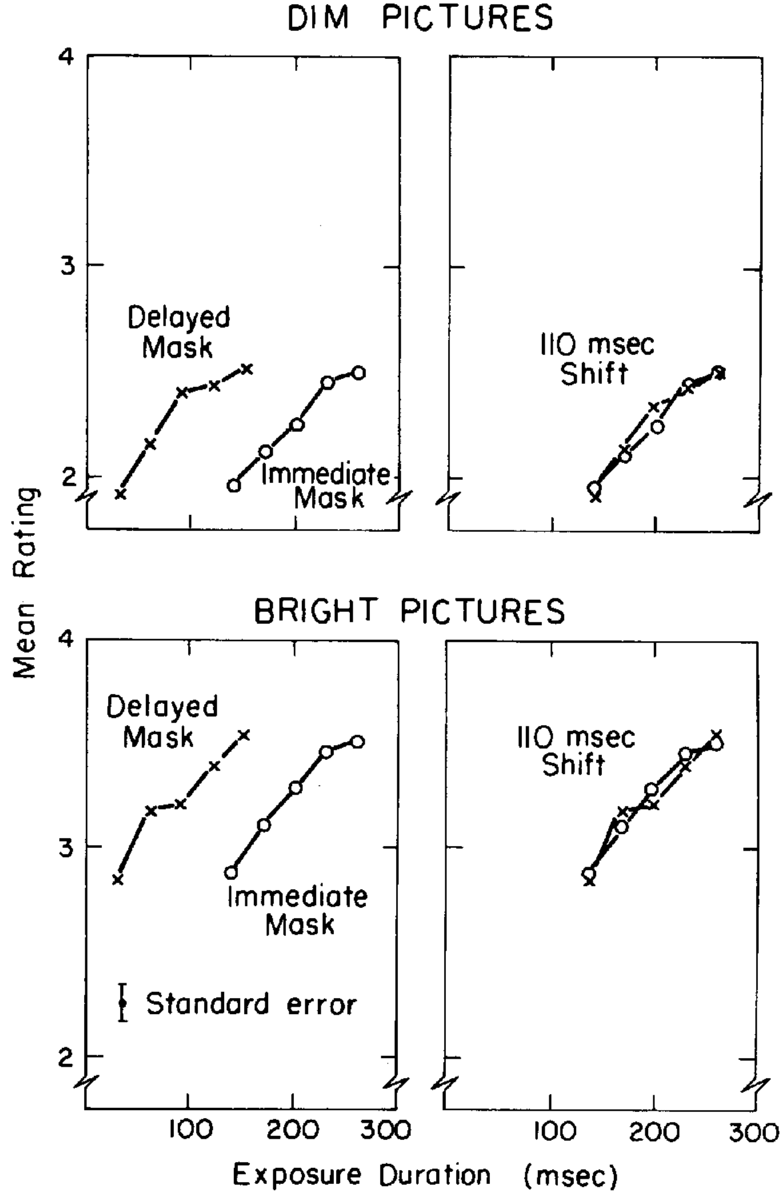

Figure 4. Experiment 4: Mean recognizability ratings as functions of stimulus exposure duration. (Top panel shows data for dim pictures, and bottom panel shows data for bright pictures. In the right-hand panels, the delayed-mask curves are displaced to the right by 110 ms. Each data point is based on 768 observations.)

less information is extracted from 110 extra ms of a dim picture than from 110 extra ms of a bright picture.

Hawkins and Shulman (1979) attribute the Keele and Chase results to an effect of luminance on "Type II persistence"—higher luminance produces an overall greater, and thus longer lasting, "strength of sensory residual" (see Hawkins & Shulman, 1979, Figure 1). The present results indicate that, in a more general sense, information extraction from the icon is tied directly to information extraction from the physical stimulus. Luminance affects both. A striking regularity emerges: The icon is worth 110 ms of additional physical exposure, independent of luminance level. This regularity could, of course, be coincidental. But it can be parsimoniously explained by assuming that the same encoding mechanisms operate during stimulus and icon. Whatever variable affects these encoding mechanisms must therefore affect stimulus and icon in identical ways.

General Discussion

An icon was found to be worth 100, 105, 110, and 110 ms in Experiments 1, 2, 3, and 4, respectively. In each experiment the value of the icon, measured in terms of additional physical exposure duration, was independent of the base duration of the picture. In Experiment 2, for example, an icon produced the same increase in performance as did an additional 105 ms of physical exposure duration, following base durations that ranged from 50 ms to 350 ms.

This finding does not, of course, imply that the absolute amount of information extacted from a picture's icon is independent of the picture's base duration. Indeed, most information-processing models assume that the rate at which information is extracted from a stimulus declines over the time during which the stimulus remains present (e.g., Kowler & Sperling, 1980; Krumhansl, 1982; Loftus & Kallman, 1979; Massaro, 1970; Rumelhart, 1969). According to these models, therefore, the amount of information acquired from the last hundred ms of the stimulus itself—and likewise, the amount of information extracted from the icon—must decline with stimulus duration. This notion accords well with a common-sense view of amount of information. If a picture is presented for a very short time—say, 100 ms—then one seems to acquire a large amount of information from it. If, in contrast, a picture is presented for a long time—say, 10 s—then one seems to acquire very little information during the last 100 ms of the presentation. Likewise, whereas a large amount of information seems to be acquired from the icon of, say, a 50-ms picture, very little information seems to be acquired from the icon of a 10-s picture.

These considerations provide a tentative explanation for the apparent discrepancies between the results of our Experiments 1 and 2 and the results of Intraub's (1980) Experiments 1 and 4. Intraub found that, with display conditions leading to a high absolute performance level, the difference between masked and unmasked pictures was small and nonsignificant. Conditions leading to high performance are exactly those under which the icon would be expected to make a relatively small contribution to the total amount of information extracted from the picture. In the present experiments, we measured the difference between masked and unmasked pictures over ranges of base exposure durations that produced wide variations in performance. Like Hulme and Merikle (1976), we found that the differences between masked and unmasked conditions were greatest at the short exposure durations where the contribution of the icon to total extracted information would be expected to be largest. This finding was most clearly illustrated in Experiment 2 (cf. Figure 2, left panel).

Psychological Equivalence

The estimated worth of an icon differed by only 10 ms over three dependent variables, four sets of pictures, and two luminance levels. The experimental procedures that we used do not permit an easy assessment of whether the 100-, 105-, and 110-ms values found in the four experiments are statistically different from one another. Intuition suggests that such a small difference in times can be ignored. We will proceed on that premise and tentatively conclude that two different physical stimuli—a *d*-ms picture with an icon and a d + 100-ms picture with no icon—lead to the same memory performance.

To what degree are these two different physical stimuli psychologically equivalent? An extreme example of stimuli that are physically different but psychologically equivalent is found in the study of color vision, wherein lights with entirely different spectral compositions can be perceived as identical. In this situation, information as to which of the physically different stimuli has been presented is lost at the receptor level—the first stage in the visual system—so the stimuli must be equivalent throughout the system.

The present situation is not as extreme. It is easy to distinguish a d-ms, delayed-mask picture from a d + 100-ms, immediate-mask picture. But these two kinds of stimuli may be equivalent at the level of memory representation. We obtained similar results for the delayed recognition test in Experiment 1, which tapped relatively long-term memory, and the detail recall and rating tests of Experiments 2–4, which tapped relatively short-term memory. It is thus reasonable to postulate that the memory representations that result from these two different stimuli—or at least the subsets of the memory representations required for our three performance tests—are equivalent at a fairly early stage.

The most extreme hypothesis permitted by our findings is that, within a second or two following stimulus offset, a d-ms picture followed by an icon and a d + 100-ms picture without an icon produce memory representations that are identical in all respects. This hypothesis, like any hypothesis, is credible to the degree that (a) attempts to disconfirm it fail and (b) evidence is found for a mechanism to account for it. The present experiments satisfy both criteria. The use of different picture sets and different ways of tapping the memory representation all produced the same value of an icon's worth. The results of Experiment 4 provided evidence that the encoding processes that extract information from the icon are the same as those that extract information from the physical stimulus.

If this mechanism, suggested by the results of Experiment 4, is indeed correct, then *any* variable (e.g., contrast, spatial frequency composition) must affect information extraction from the icon in exactly the same way as it affects information extraction from the physical stimulus. This, in turn, would mean that the icon must always be worth 100 ms when measured in terms of the physical stimulus that it follows. In this sense, an icon's worth would be a constant of the perceptual system.

Perceptual and Conceptual Processes

The superiority of the no-mask over the delayed-mask conditions in Experiment 1 indicates that encoding processes, susceptible to disruption by a noise mass, continue to operate past 300 ms following stimulus offset. Potter (1976) and Loftus and Ginn (1984) have suggested that picture perception involves (at least) two qualitatively different processes. Perceptual processes operate on a picture or its icon and result in the identification of the picture. Conceptual processes operate on the output of perceptual processes, are subject to attentional strategies, and result in a representation of the picture that can be used in a subsequent memory test. Within this framework, perceptual processes are completed by 300 ms, and a delayed mask exerts its influence on memory performance by impairing conceptual processes.

Icon Worth Versus Icon Duration

It is important to distinguish between an icon's *worth,* as measured in the present experiments, and an icon's *duration,* as measured, for example, by temporal integration (e.g., DiLollo, 1980; Eriksen & Collins, 1967), synchrony judgment (e.g., Efron, 1970a, 1970b; Sperling, 1967), and other paradigms (see Coltheart, 1980, for a review). The exact relationship between worth and duration is not immediately evident. If the icon remained *identical* to the physical stimulus throughout its existence and then abruptly vanished, then worth and duration would be the same. An icon is generally not assumed to act this way, however. Rather, it is assumed to fade. Given that the icon does fade—that it becomes progressively less valuable as a source of information over the course of its existence—the icon's worth must be less than its duration. A typical estimate of the icon's duration is on the order of 250 ms. The estimate of 100 ms for the icon's worth is thus reasonable.

It has been shown that the subjective duration—the persistence—of an icon decreases with increasing stimulus duration and stimulus luminance (Bowen, Pola, & Matin, 1974; Efron, 1970a, 1970b; DiLollo, 1980; Haber & Standing, 1970). We have replicated these effects with complex pictures (Loftus & Shimamura, 1985). At first glance, the dependence of persistence on exposure duration and luminance seems inconsistent with the present finding that the icon as a basis for information extraction is independent of these variables. Indeed Coltheart (1980) cites this kind of inconsistency as evidence that visual persistence and information extraction result from different mechanisms.

We believe, however, that the two phenomena can be integrated within a single model that assumes (a) perceptual processes consist of the extraction of information from the picture or its icon, (b) the rate of information extraction declines as a function of the amount of information already extracted, and (c) the icon remains phenomenologically present until the information-extraction rate falls below some criterion.

According to this model, stimulus duration would affect persistence as follows. Following a short-duration (e.g., 50-ms) picture, information extraction rate would still be high at the time the stimulus ended and the icon began; hence it would take a long time for rate to fall to some criterion. Conversely, following a long-duration (e.g., 300-ms) picture, rate would be relatively lower when the picture ended and thus would take a relatively shorter time to fall to the same criterion.

The effect of luminance on persistence is, according to the model, somewhat more complex. A bright picture would start with a higher information-extraction rate than would a dim picture; hence more information would be extracted overall. However, because the relevant information would be extracted faster from a bright than from a dim picture, the rate would drop more quickly. Eventually, the bright-picture rate would drop below the dim-picture rate; thus, under some circumstances, the rate would remain above criterion longer for a dim than for a bright picture. The details of this model, and its fit to the data, will be described in a subsequent article.

References

Adelson, E. H., & Jonides, J. (1980). The psychophysics of visual storage. *Journal of Experimental Psychology: Human Perception and Performance, 6,* 486–493.

Bowen, R. W., Pola, J., & Matin, L. (1974). Visual persistence: Effects of flash luminance, duration and energy. *Vision Research, 14,* 295–303.

Coltheart, M. (1980). Iconic memory and visible persistence. *Perception & Psychophysics, 27,* 183–228.

DiLollo, V. (1980). Temporal integration in visual memory. *Journal of Experimental Psychology: General, 109,* 75–97.

Efron, R. (1970a). Effect of stimulus duration on perceptual onset and offset latencies. *Perception & Psychophysics, 8,* 231–234.

Efron, R. (1970b). The relationship between the duration of a stimulus and the duration of a perception. *Neuropsychologia, 8,* 37–55.

Eriksen, C. W., & Collins, J. F. (1967). Some temporal characteristics of visual pattern perception. *Journal of Experimental Psychology, 74,* 476–484.

Haber, R. N., & Standing, L. (1970). Direct estimates of the apparent duration of a flash. *Canadian Journal of Psychology, 24,* 216–229.

Hawkins, H. L., & Shulman, G. L. (1979). Two definitions of persistence in visual perception. *Perception & Psychophysics, 25,* 348–350.

Hulme, M. R., & Merikle, P. M. (1976). Processing time and memory for pictures. *Canadian Journal of Psychology, 30,* 31–38.

Intraub, H. (1980). Presentation rate and the representation of briefly glimpsed pictures in memory. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 1–12.

Keele, S. W., & Chase, W. G. (1967). Short-term visual storage. *Perception & Psychophysics, 2,* 383–385.

Kowler, E., & Sperling, G. (1980). Transient stimulation does not aid visual search: Implications for the role of saccades. *Perception & Psychophysics, 27,* 1–10.

Krumhansl, C. (1982). Abrupt changes in visual stimulation enhance processing of form and location information. *Perception & Psychophysics, 32,* 511–523.

Loftus, G. R. (1982). Picture memory: Data and methodology. In C. R. Puff (Ed.), *Handbook of research methods in human memory and cognition* (pp. 257–285). New York: Academic Press.

Loftus, G. R. (in press). Picture perception: Effects of luminance on available information and information-extraction rate. *Journal of Experimental Psychology: General.*

Loftus, G. R., & Bell, S. M. (1975). Two types of information in picture memory. *Journal of Experimental Psychology: Human Learning and Memory, 104,* 103–113.

Loftus, G. R., & Ginn, M. (1984). Perceptual and conceptual masking of pictures. *Journal of Experimental Psychology: Learning, Memory and Cognition, 10,* 435–441.

Loftus, G. R., & Kallman, H. J. (1979). Encoding and use of detail information in picture recognition. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 197–211.

Loftus, G. R., & Shimamura, A. P. (1985). *Picture perception: Information extraction and visual persistence* Manuscript in preparation.

Long, G. M., & Beaton, R. J. (1982). The case for peripheral persistence: Effects of target and background luminance on a partial-report task. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 383–391.

Massaro, D. W. (1970). Perceptual processes and forgetting in memory tasks. *Psychological Review, 77,* 557–567.

Neisser, U. (1967). *Cognitive psychology.* New York: Appleton-Century-Crofts.

Potter, M. C. (1976). Short-term conceptual memory for pictures. *Journal of Experimental Psychology: Human Learning and Memory, 2,* 509–522.

Potter, M. C., & Levy, E. I. (1969). Recognition memory for a rapid sequence of pictures. *Journal of Experimental Psychology, 81,* 10–15.

Rumelhart, D. E. (1969). A multicomponent theory of the perception of briefly exposed visual displays. *Journal of Mathematical Psychology, 7,* 191–218.

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs, 74,* 1–29.

Sperling, G. (1963). A model for visual memory tasks. *Human Factors, 5,* 19–31.

Turvey, M. T. (1973). On peripheral and central processes in vision: Inferences from an information-processing analysis of masking with patterned stimuli. *Psychological Review, 80,* 1–52.

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Editor for *Psychological Bulletin* Named: Search for New Editor Continues

David Zeaman, editor of *Psychological Bulletin,* died on July 19, 1984. Betty J. House, Zeaman's colleague at the University of Connecticut, and one of the journal's associate editors, will complete David Zeaman's term and serve as editor through 1986. Effective immediately, authors should submit manuscripts to:

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