DOCUMENT RESUME

ED 140 990 PS 009 391

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TITLE Icon Duration and Development.
SPONS AGENCY National Inst. of Child Health and Human Development (NIH), Bethesda, Md.
PUB DATE Mar 77
GRANT NICHD-HD-C7614
NOTE 21p.; Paper presented at the Biennial Meeting of the Society for Research in Child Development (New Orleans, Louisiana, March 17-20, 1977)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS Adults; *Age Differences; Elementary School Students; *Females; *Memory; *Research Methodology; *Visual Perception; *Visual Stimuli
IDENTIFIERS *Iconic Storage

ABSTRACT

In this study, developmental changes in duration of the icon (visual sensory store) were investigated with three converging tachistoscopic tasks. (1) Stimulus interuption detection (SID), a variation of the two-flash threshold method, was performed by 29 first- and 32 fifth-graders, and 32 undergraduates. Icon duration was estimated by stimulus interruption that resulted in 75% performance. Results suggest that the icon lasts longer in younger subjects. (2) Letter detection (LD), an adaptation of the Estes and Taylor detection method, estimated effective icon duration as the shortest interval between the stimulus field and noise mask that resulted in equivalent-to-unmasked performance. Data were collected over seven sessions with ten 6- to 11-year-old females. No strong relation between age and iconic duration was apparent. (3) Judgement of cyclic stimulus disappearance, fashioned after Haber's direct method consisted of a letter matrix, alternating with a blank field. As the blank field increased in duration, the LD subjects judged when the letters seemed to disappear and when the letters seemed to remain on continuously as the blank field duration was decreased. The results indicate no strong evidence for a change in icon duration with age. Methodological issues were examined in comparing the results of the three approaches. The age difference in SID can be attributed to factors other than icon duration. The evidence favors the view that icon duration is constant across age. (Author/MS)

ICON DURATION AND DEVELOPMENT[1]

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Presented at the Biennial Convention of the
Society for Research in Child Development
New Orleans, Louisiana, March 17, 1977

We have been investigating the development of visual perception from an information processing perspective (see also Gummerman, Ersoff, Leitner, & Chastain, 1975). Today we wish to discuss the icon, the earliest stage in many models of visual information processing. The icon may be considered a positive image that is not yet analyzed; the information available in it closely resembles the optical array. The memorial aspects of the icon are emphasized by other names like "iconic storage" and "visual sensory store." This type of storage is quite brief in adults, less than a second in a lighted environment.

Our present concern is whether the duration of this storage changes with development. If there is an age-related change in iconic duration, there are implications for developmental perceptual methodology as well as for theories of perceptual development.

To examine the relationship between age and iconic duration, three methods were used: detection of stimulus interruption, stimulus disappearance judgment, and letter detection with backward masking. By using three different approaches, we hoped to avoid attributing effects to iconic duration that are in fact due to particular experimental situations.

DETECTION OF STIMULUS INTERRUPTION

This method involves the detection of interruption in a stimulus presentation. The underlying reasoning is similar to that of the "two-flash threshold" or the "dark-interval threshold" (see Pollack, Ptashne, and Carter, 1969; Thor, 1970; Thor & Thor, 1970). The participant observes a brief stimulus, in our case a solid black circle, and decides whether the circle was on continuously (Figure 1, panel B) or was briefly interrupted (Figure 1, panel A). We used a forced-choice psychometric procedure to minimize the influence of response bias: On half the trials, the stimulus was interrupted by a blank illuminated field, and on the other trials it was continuous.

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1. This research was supported by grant HD07614 from the National Institute of Child Health and Human Development and conducted when the first author was at the University of Texas at Austin. We are very grateful for the cooperation of the Austin, Texas, Independent School District, the principal and staff of Cunningham Elementary School, the director and staff of the Tarrytown Baptist Church child care center, and the subjects and their parents. Requests for reprints may be sent to Kent Gummerman, Special Projects Bureau, Texas State Department of Public Welfare, John H. Reagan Bldg., Austin, TX 78701.

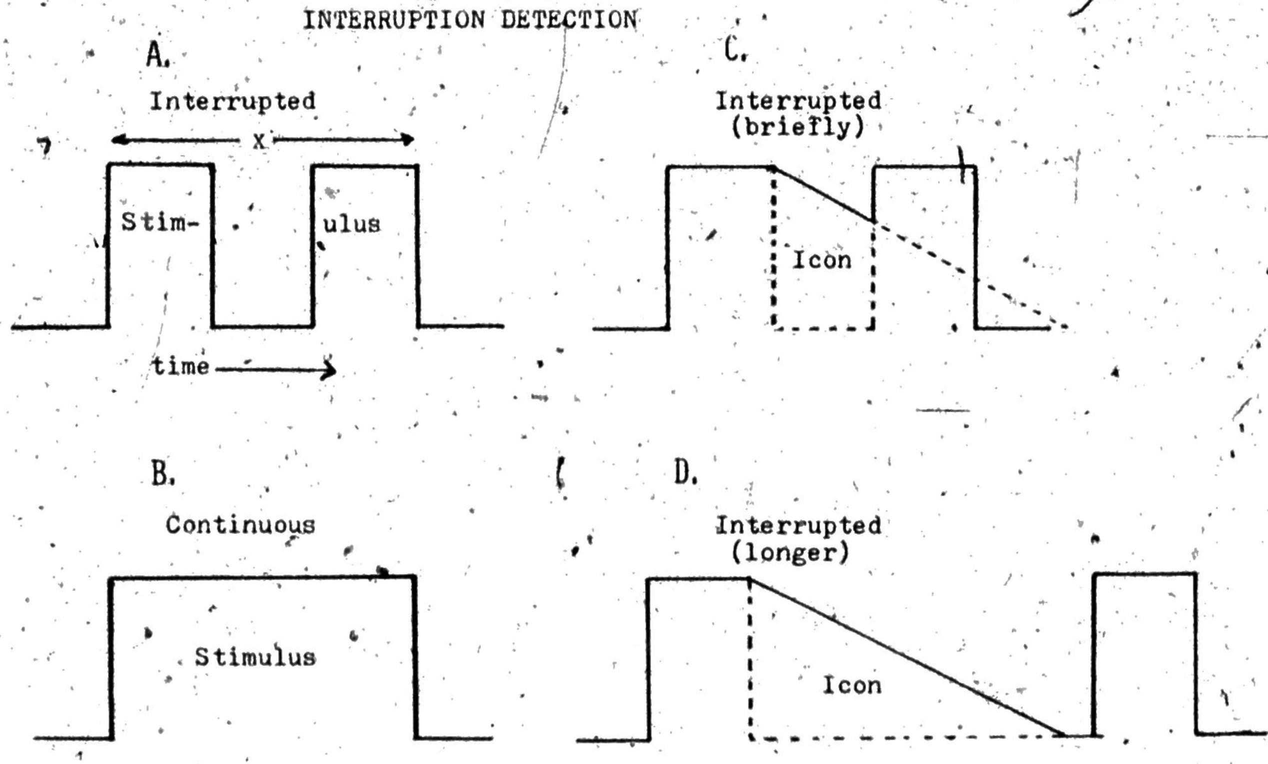

INTERRUPTION DETECTION
A.
Interrupted
x
Stim-
ulus
time
C.
Interrupted
(briefly)
Icon
B.
Continuous
Stimulus
D.
Interrupted
(longer)
Icon

FIGURE 1

How does performance on this task relate to iconic duration? Consider the case of stimulus interruption. We assume the first stimulus presentation is followed by an icon (Figure 1, panel C) during the blank interval. This icon "fills in the gap" so that, with a short interruption, the interrupted presentation is difficult to discriminate from the continuous one. With very long interruptions (Figure 1, panel D), the icon ends before the second presentation, providing a situation easily discriminable from the continuous trials.

The duration of the interruption varied from 0.005 to 0.360 sec in separate blocks of trials. The interval from the onset of the first stimulus presentation to the end of the second (interval X in Figure 1, panel A) determined the duration of the continuous trials in each block. Thus the observer could not distinguish the continuous trials from the interrupted trials simply on the basis of total duration. Twenty-nine first-graders, 32 fifth-graders, and 32 college undergraduates participated in this study.

The proportion of correct responses was calculated for each interval of interruption, or interstimulus interval (ISI). Figure 2 illustrates the performance of each age group. A logarithmic function was fitted to each subject's data, and the ISI corresponding to performance of 0.75 (halfway between chance and perfect) was taken as the measure of relative icon duration. (This procedure did result in a few anomalous scores. An outstanding example was the fifth-grader whose iconic duration came to a bit over 259 years. Six such scores were deleted because they were greater than three standard deviations from the group mean, calculated using the score in question. This 7% subject loss was fairly evenly distributed over the age and sex groups, so it reduced variance to reasonable levels without altering the pattern of results.)

There was a strong and significant age effect, with young subjects requiring longer interruptions to perform as well as the older ones.

This outcome apparently indicates that icon duration is greater in younger perceivers, but the age effect does have an alternative interpretation. The task requires distinguishing between the dwindling icon and the onset of the second stimulus presentation. In the left side of Figure 3, the age effect we obtained is illustrated as the result of differences in icon duration. Alternatively, as the right half of the figure shows, the age effect could be due to the perceivers' sensitivity to differences in icon duration. Alternatively, as the right half of the figure shows, the age effect could be due to the perceivers' sensitivity to differences in stimulus and icon brightness (labeled d). That is, the younger perceivers may require the icon brightness from the first part of the stimulus to diminish considerably before it can be discriminated from the onset of the second part of the stimulus. In the example of Figure 3 (panels C and D), even though the icon is the same duration in the two groups, the advantage of greater sensitivity in the older group produces the obtained age effect. Consequently, the results of the study, while consistent with the notion that icon duration decreases with development, are ambiguous. Another approach is needed to justify the duration interpretation.

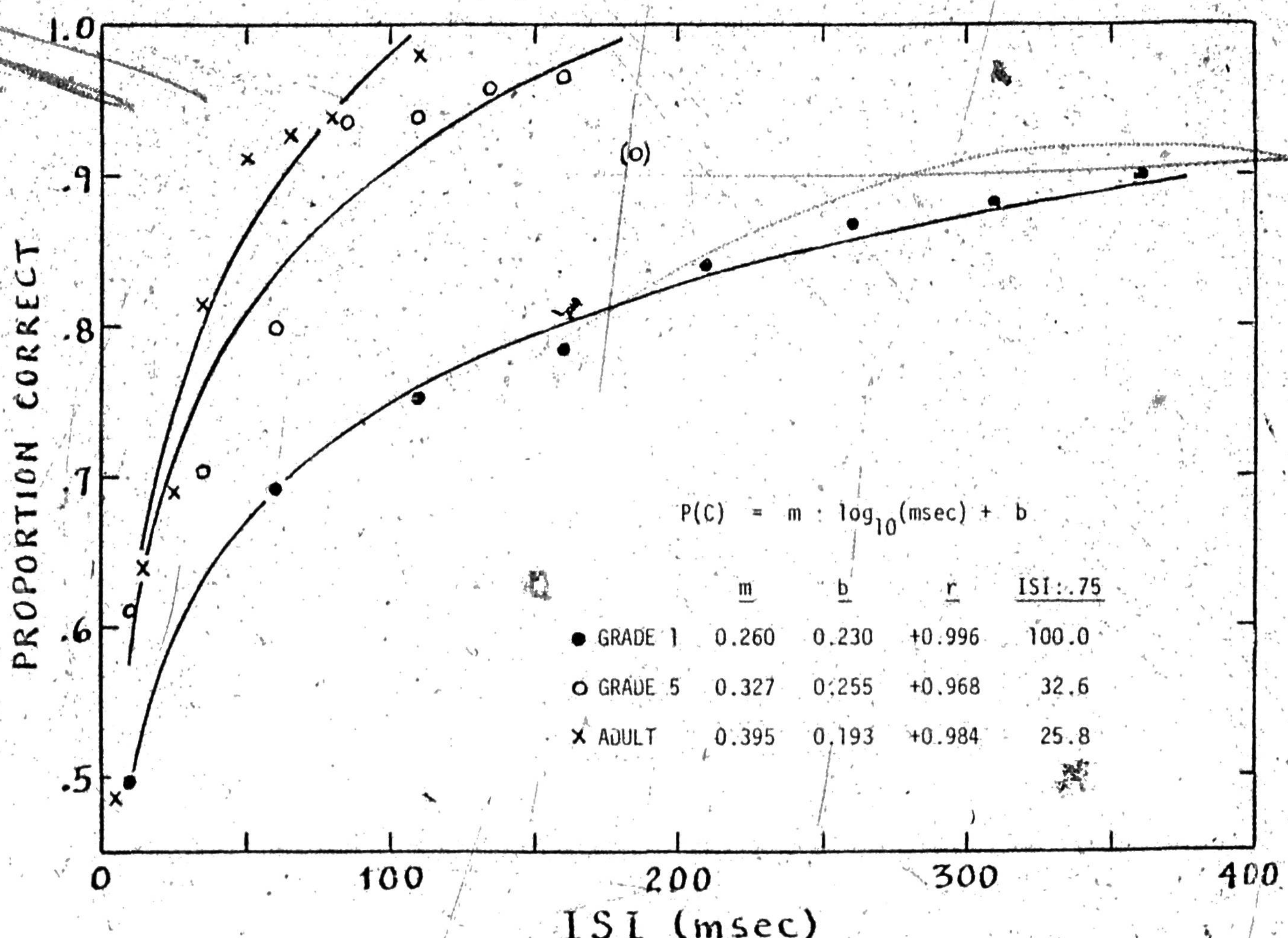

PROPORTION CORRECT
1.0
.9
.8
.7
.6
.5
0
100
200
300
400
ISI (msec)
(o)
P(C) = m · log10(msec) + b
m b r ISI:.75
● GRADE 1 0.260 0.230 +0.996 100.0
o GRADE 5 0.327 0.255 +0.968 32.6
X ADULT 0.395 0.193 +0.984 25.8

FIGURE 2.

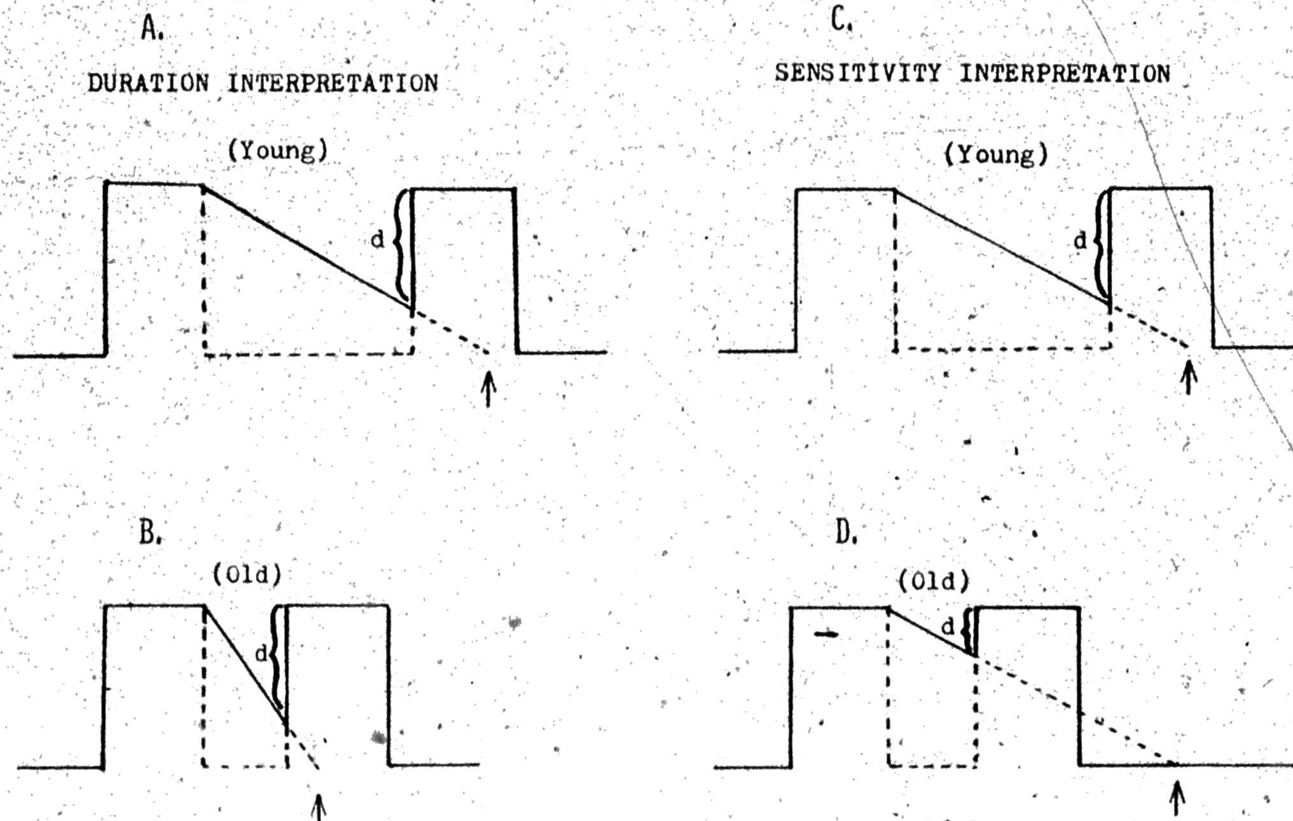

A.
DURATION INTERPRETATION
(Young)
d
C.
SENSITIVITY INTERPRETATION
(Young)
d
B.
(Old)
d
D.
(Old)
d

FIGURE 3

STIMULUS DISAPPEARANCE JUDGMENT

The second method to be discussed is judgment of the disappearance of a cyclic stimulus. It is a variation of the "direct" method for measuring icon duration (Haber & Standing, 1969; Standing, Haber, Cataldo, & Sales, 1969). The participants (ten females ranging in age from 6 to 11 years) viewed the stimulus, a matrix of letters, that lasted for 0.020 sec. This stimulus alternated continuously with a blank field of variable duration (see Figure 4). With a brief blank period, the stimulus appeared to grow dimmer and brighter through each cycle, but never quite disappeared altogether. As the experimenter increased the blank field duration, the observer judged when the stimulus seemed to completely disappear on each cycle. Conversely, the observer also judged when the letters appeared to remain on continuously as the blank field duration was decreased from a very long value that produced obvious disappearance. These ascending and descending scores were averaged to yield a "direct" estimate of icon duration.

The scores showed no clear relation with age ($r = +0.28$, n.s.). A stronger relation was found between the age of the observers and the variability of their scores ($r = -0.45$, n.s.), indicating that it was difficult for the young subjects to follow the instructions and maintain a consistent criterion over the course of the study. This method, then, does not seem appropriate to use with young children.

LETTER DETECTION WITH BACKWARD MASKING

When we view the world with successive fixations, why does not the icon of each fixation interfere with the subsequent one? One reason why these "snapshots" of the world do not overlap to form a meaningless jumble is the phenomenon known as backward masking ("masking" because a visual input masks or inhibits the processing of other visual information, and "backward" because the effect appears to operate backward in time). For related developmental studies using masking procedures, see Blake (1974) and Welsandt, Zupnick, and Meyer (1973).

To illustrate the method, consider Figure 5. Suppose we first instruct observers to decide whether a "K" or an "F" is presented. We allow them to view some letters for a brief period (we used 0.020 sec) and follow the letters with a plain illuminated field. Typically, the observers will respond correctly (in this example "K") most of the time. However, if we introduce a two-second visual "noise" mask immediately after the letters, performance is greatly reduced. Consideration of the icon provides a convenient analysis of this backward masking effect.

In the unmasked situation (Figure 6, panel A), the perceivers are presumably using iconic storage to help detect the letter. When the stimulus is immediately followed by a mask (Figure 6, panel B), the icon is no longer accessible to the observers. (For the present purpose, we need not be concerned with exactly how the mask affects the icon. It may interrupt processing of iconic information, or it may actually be integrated with the icon to produce the meaningless jumble we mentioned earlier. In either case, the important point is that the information in

CYCLIC STIMULUS DISAPPEARANCE

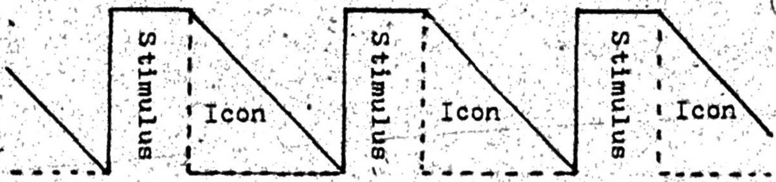
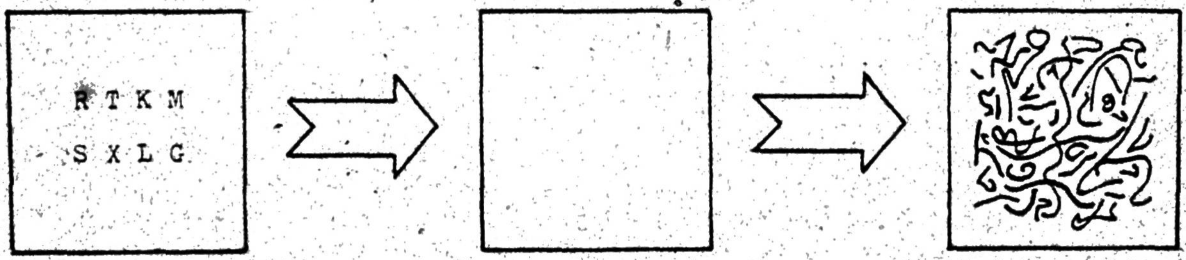


FIGURE 4



.02 second VARIABLE 2 seconds

FIGURE 5

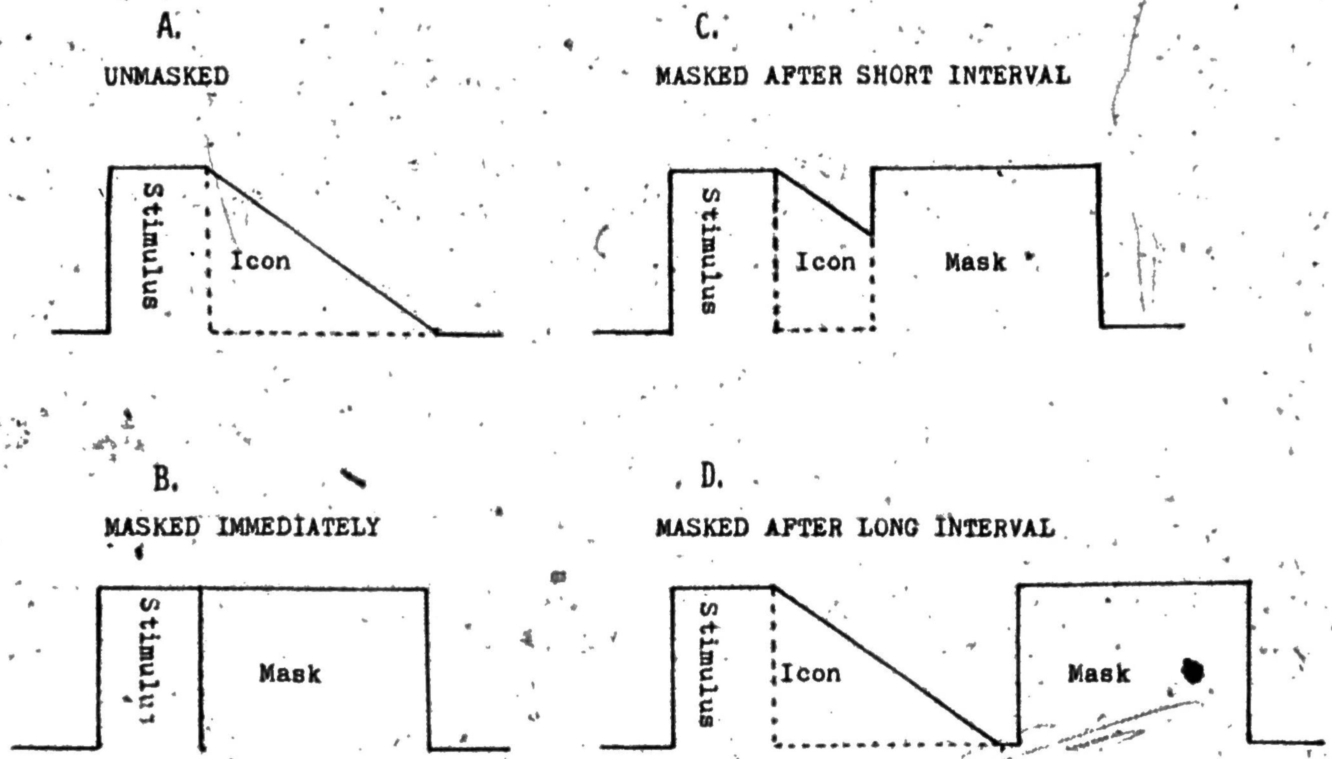

A.
UNMASKED
Stimulus
Icon
C.
MASKED AFTER SHORT INTERVAL
Stimulus
Icon
Mask
B.
MASKED IMMEDIATELY
Stimulus
Mask
D.
MASKED AFTER LONG INTERVAL
Stimulus
Icon
Mask

FIGURE 6

the icon ceases to be available for further processing when the mask is presented.) We can estimate the icon's duration by determining the longest interval after the stimulus over which the mask affects performance. At short intervals (Figure 6, panel C), letter detection should be poorer than at longer intervals (Figure 6, panel D) since iconic information is available only briefly with short intervals.

Performance something like Figure 7 was anticipated. At very brief intervals between stimulus and mask, very little icon is available for the letter detection task, so performance should be poor. At longer intervals, more of the icon may be used, so performance should improve. At an interval equivalent to iconic duration, the highest level of performance is reached. Once the interval is as long as the icon, no additional improvement in performance can be realized by further increasing the interval. Therefore, we may take the shortest interval by which performance has peaked as an estimate of effective icon duration.

There are two fundamental requirements of this backward masking method: One is the granting of a simplifying assumption, and the other is a performance stipulation.

We say that we are estimating the effective icon duration because it is possible that some remnants of the decayed icon are present after performance levels off but are not informative for the observer's task. As long as one grants the assumption that the minimum useful value does not interact with age, the backward masking method should provide an index or indirect estimate of relative iconic duration for perceivers of different ages.

The second requirement is critical to the logic underlying our method of duration estimation. It specifies that the level of each subject's maximum performance must be clearly less than the task ceiling of 100%. Figure 8 illustrates the effect of permitting ceiling performance. The upper left shows a relatively short icon with task ceiling reached within its duration. On the right is the resulting performance. The attainment of maximum performance produces our estimate of the icon's duration, but in this case maximum performance indicates only that the task requirements are completely met, not that information from the icon is no longer available. The consequences of 100% performance become clearer when we compare the top row of Figure 8 to the bottom. Here the icon lasts longer, but once again maximum performance level is attained at an interval corresponding to reaching the task ceiling rather than iconic duration. In comparing the two performance curves, we would mistakenly estimate iconic duration to be equal. It is critical, then, to insure that all subjects perform at less than ceiling.

The same females that participated in the second experiment took part in this one. They were asked on each trial to decide whether a matrix of letters presented for 0.020 sec contained a "K" or an "F". The experiment was conducted over a total of eight sessions. Based on a practice session, the number of letters in the matrix was adjusted so that performance, even in an unmasked condition, was less than 100%. Each subject's performance was plotted. These graphs were given to four raters who independently judged the shortest masking interval at which maximum performance (equivalent to unmasked performance) was reached. These ratings were done

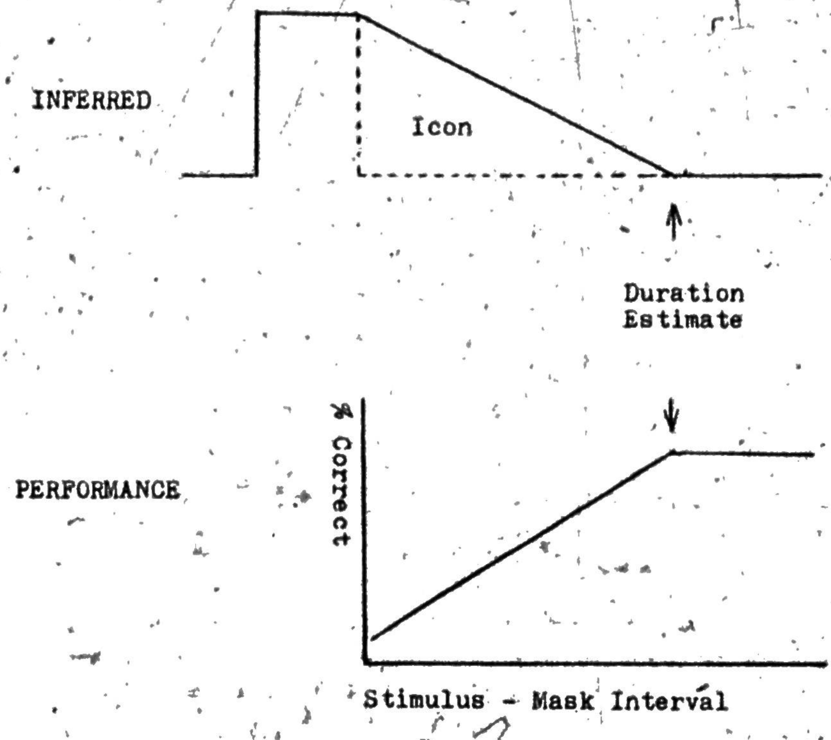

INFERRED
Icon
Duration
Estimate
PERFORMANCE
% Correct
Stimulus - Mask Interval

FIGURE 7

EFFECT OF 100% PERFORMANCE

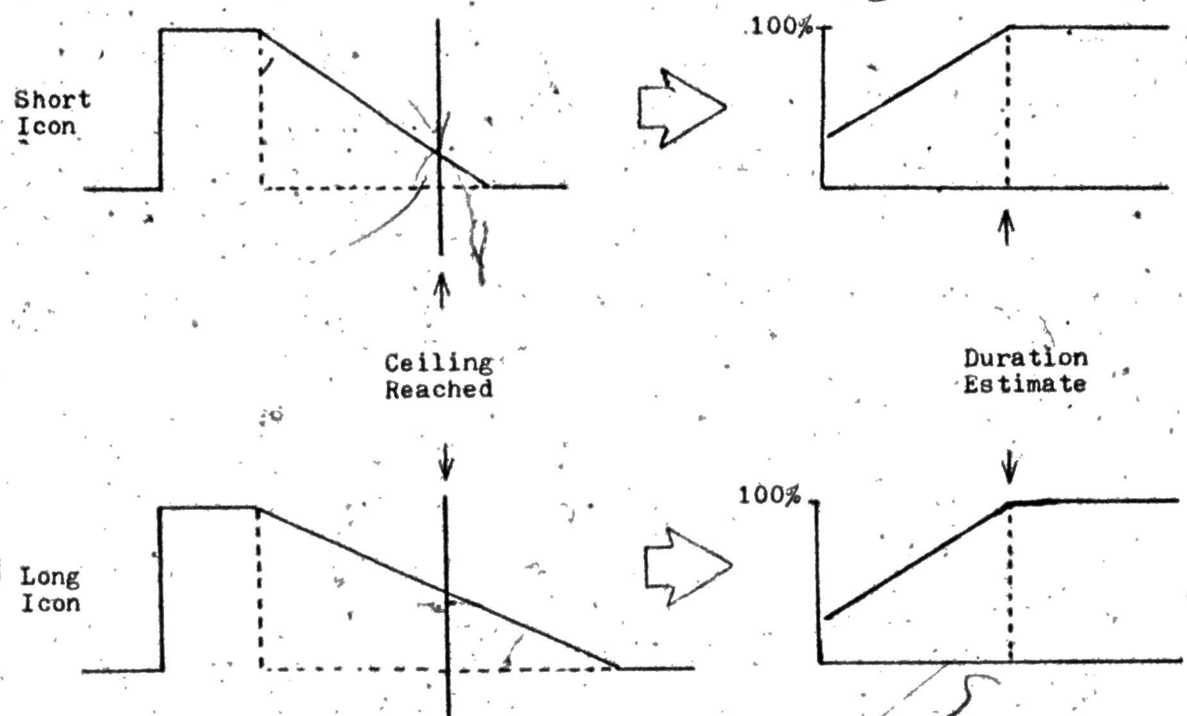


FIGURE 8

without knowledge of the subject's age. Inter-rater correlations were excellent (between + 0.88 and +0.95), reflecting the quality of the masking functions obtained.

The mean estimates of relative icon duration were compared with the perceivers' ages (Figure 9), and a positive (but nonsignificant) correlation of + 0.35 was obtained, hinting that perhaps <u>older</u> children have longer icons. There were considerable individual differences in icon duration in the few participants included in our study, and we suggest that future efforts along these lines either include more subjects or pursue a short-term longitudinal strategy.

CONCLUSIONS

We feel it is wise to discount the results from the second study (stimulus disappearance judgment) since criterion problems seem to make it inappropriate for use with young children. The results of the first study (stimulus interruption) are consistent with the notion that icon duration decreases with age, but it is vulnerable to the alternative sensitivity-change interpretation.

The backward masking task appears to be the most promising (as long as ceiling performance is avoided). Although we found no significant relation between age and estimated icon duration, the trend was toward increasing icon duration with development, just the opposite of the stimulus interruption detection results and contrary to hypotheses we have held for some time. At this point it would seem best to draw this rather guarded conclusion: There is no firm evidence that the icon's duration changes with age in any way.

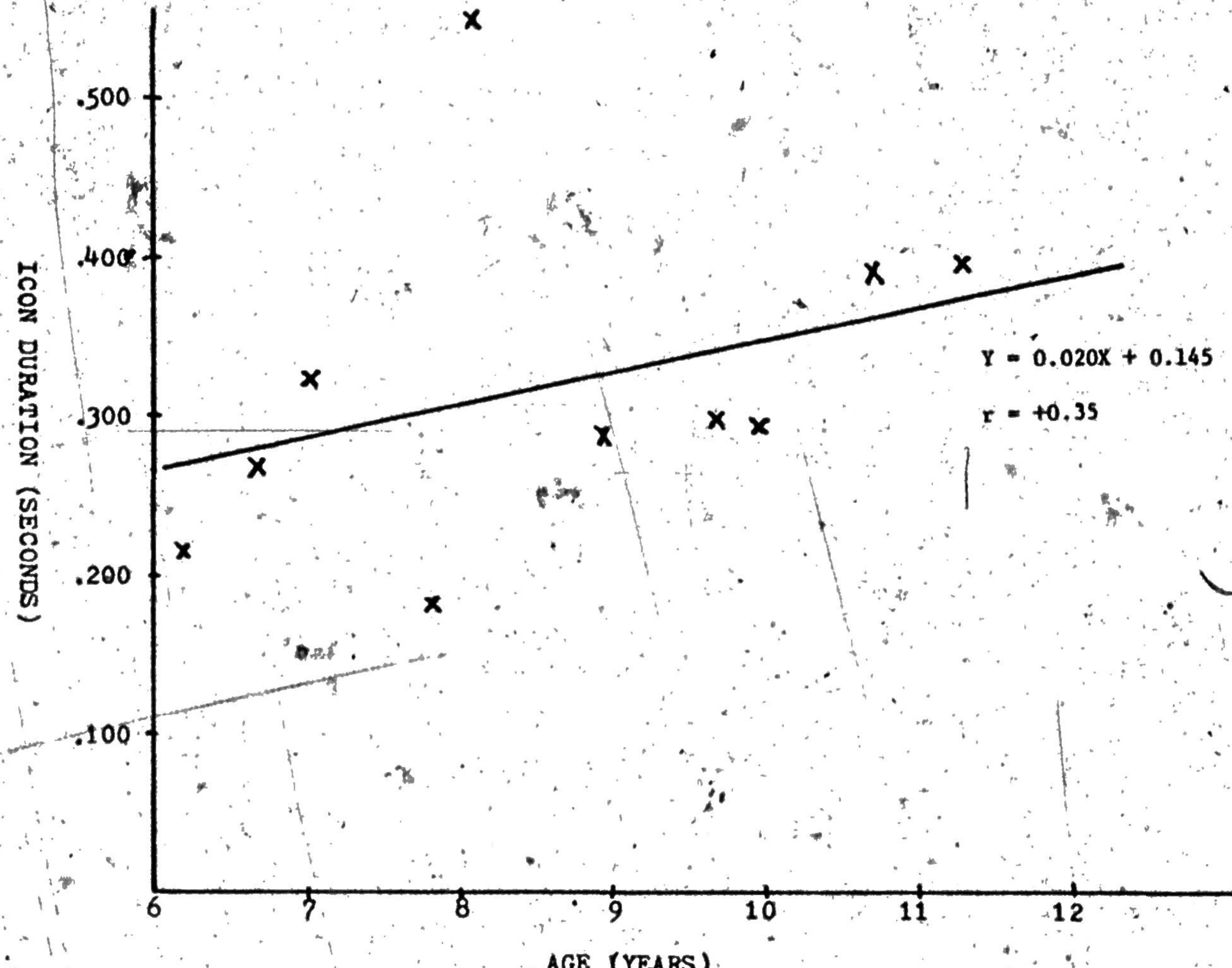

.500
.400
.300
.200
.100
ICON DURATION (SECONDS)
6
7
8
9
10
11
12
AGE (YEARS)
Y = 0.020X + 0.145
r = +0.35

FIGURE 9

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