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AUTHOR Meyer, Philip A.
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ABSTRACT

Reported were four experiments which investigated the developmental and mental retardation aspects of an initial stage of visual information processing termed iconic memory. The stage was explained to involve processing visual stimuli prior to sensation and through to recognition. In three of the four experiments, the paradigm of visual masking was used to determine the speed or efficiency of information processing; the Crawford-pattern mask technique was used throughout. The four experiments were titled age effects on backward visual masking, adult age effects on backward visual masking, forward and backward masking with normal and retarded subjects, and iconic storage and information availability by normal and retarded subjects, respectively. Subjects in the four experiments ranged in age from 5 to 55 years of age. Major findings of the experiments were reported to be development and documentation of a methodology surmounting previous problems in studying development and mental retardation aspects of iconic memory, establishment of relationship between age variable and efficiency with which visual information is processed, and poorer performance by retarded subjects on iconic memory tasks than by normal subjects matched in terms of mental age. (CB)

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A COMPARISON OF THE EFFECTS OF INTERFERENCE AND DISTORTION IN VISUAL INFORMATION PROCESSING BY NORMAL AND RETARDED CHILDREN AND BY ADULTS

Philip A. Meyer
Department of Psychology
University of South Dakota
Vermillion, South Dakota 57069

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TABLE OF CONTENTS

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INTRODUCTORY SECTION

Summary. This research project investigated the developmental and mental retardation aspects of a most important initial stage of visual information processing, termed *iconic memory*. This stage involves processing visual stimuli prior to sensation and through to recognition. A general experimental paradigm for determining the speed or efficiency of such processing was employed in three of the four experiments conducted. This paradigm is known as *visual masking* and the Crawford-pattern mask technique was used throughout.

The first three experiments provided significant and exceptionally clear data on developmental relationships for the efficiency of iconic memory. Statistically significant relationships with normal children from four groups (5, 10, 16, 22-23 years old) were obtained in the first study indicating faster iconic processing with increasing age. This relationship occurred in the absence of any real differences among age groups in recognition accuracy apart from the masking paradigm. A second experiment extended the age range of the first employing normal adults in three groups (18, 35, 55 years old). A small age effect was obtained indicating some slight reduction in the efficiency of iconic memory for the oldest subjects. Taken together, these two experiments most clearly establish the role of development in efficient, pre-recognition processing of visual information. From these results, the slower processing of children is also apparent. A question of great interest given these age effects is what process or processes contribute to the improved efficiency of iconic memory with age?

A major objective of this research project was to investigate the proficiency of iconic memory with retarded subjects. Some previous research had suggested differences in tasks related to iconic memory between retarded and normal children. Thus, experiments were conducted each comparing "familial" moderately retarded subjects(RS), having an average mental age score of 111.4 months, with two groups of normal subjects. One group was equated to the RS group in terms of chronological age, the ECA group; the second group was equated in terms of mental age, the EMA group.

In the first of these experiments, the same visual masking task was used as in the previously described studies. The results indicated statistically significant group effects. Furthermore, the RS group exhibited slower iconic processing than both the ECA and EMA groups. The RS-EMA difference suggests that retardation per se is involved in the deficient performance of retardates and that mental age cannot alone account for the impaired iconic memory evidenced in these results.

The second experiment with retarded subjects employed a partial report technique (Averbach & Coriell, 1961; Sperling, 1960) to examine the duration of the image retained in iconic memory for processing. This technique requires subjects to recognize one of several items displayed together. The specific item selected is signalled at varying delays by a visual indicator. When the RS, ECA, and EMA groups were compared on this task, significant group differences occurred indicating that the ECA group performed better than the EMA group, which in turn was significantly superior to the RS group. Thus visual information in iconic memory is less available or decays sooner for retarded subjects than for normal subjects. This deficiency in iconic memory, like the previously obtained deficiency, is not interpretable solely in terms of mental age effects and thus is an effect of retardation per se.

The several findings described above constitute some clear and extensive evidence regarding the role of developmental and intellective influences on efficient and accurate processing of visual information prior to recognition, i.e., iconic memory. In addition to demonstrating iconic memory dysfunction for retarded subjects in terms of processing speed and retention, the present pattern of results imply that iconic memory functioning may be modifiable by experience, since normal subjects improve with age and older retarded subjects do poorer than younger mental age control subjects on iconic memory tasks. Much research still needs to be done to increase our knowledge of iconic memory; however, several specific recommendations for projects may be offered at this time: (1) greater understanding of the processes contributing to the visual iconic memory dysfunction of retardates should be sought; (2) initial investigations of iconic memory in the auditory mode which deal with developmental and retardation effects should begin; (3) a training procedure to improve iconic memory processes in children should be developed and evaluated.

Background and Introductory Information. The present report describes the methods, results, and implications of four experiments designed to furnish information concerning the influence that developmental and mental retardation factors have on an initial stage of visual information processing. This stage is called iconic memory (Neisser, 1966). Iconic memory may be conceptualized as a representation of the visual sensation which briefly outlasts the external stimuluation in order to permit further processing through recognition and short-term memory.

Two lines of research have helped define iconic memory. The first research area is termed visual masking. Visual masking may be defined as a reduction of the accuracy of identification of a target stimulus(TS) produced by non-contiguous presentation of another stimulus, the masking stimulus(MS). When TS duration is sufficient for identification, the MS may be presented after TS offset and still interfere with recognition. Obviously then, TS duration is insufficient time for identification. Thus, pre-recognition processing occurs after TS offset and is susceptible to interference by subsequent MS presentation. The processing after TS offset is evidence for an information processing stage which operates even prior to stimulus recognition. The stimulus parameters which govern the extent and magnitude of visual masking have been reviewed in great detail (cf. Kahneman, 1968).

Data employing dichoptic visual presentations of TS and MS, i.e., presenting TS and MS to separate eyes, have clearly demonstrated the central or cognitive aspect of iconic memory. Only pattern MSs have yielded such results; therefore, a pattern mask was used exclusively in this research. In addition, several other characteristics which are essential for adequate experimental investigations dealing with developmental effects of iconic processes were implemented. First, a wide range of ages was examined. Second, equivalent performance among age groups in an unmasked condition (i.e., straight TS recognition) was clearly demonstrated prior to recognition. Third, feedback and verbal reinforcement were implemented to provide the motivation necessary for peak performance in all subjects. Fourth, data from all interstimulus interval values used were analyzed, in order to give a complete picture of masking effects. Unlike previous research on age effects (e.g., Pollack, 1965; Spitz & Thor, 1968), the experiments in this project utilized all the methodological characteristics enumerated above. In this manner, a truly accurate analysis of developmental changes in susceptibility to visual masking was obtained.

The second area of research which has extended our knowledge of iconic memory is known as the partial report technique (Averbach & Coriell, 1961; Sperling, 1960). This technique involves a recognition task in which a complex, multi-element, target display is presented. Conditions of display are such that full report of the display elements (e.g., letters) following presentation is considerably less than perfect, e.g., 60% correct. This performance level may reflect several sorts of processing limitations. In the partial report technique, an indicator or cue which designates one or some subgroup of elements is presented following the display. Under these conditons, subjects report only the designated element(s). Over a series of such trials, a performance level may be obtained which is usually higher than under full report conditions (e.g., 95% vs. 60%). Hence, the partial report technique demonstrates the availability of considerably more elements than suggested by performance under full report conditions. By varying the delay of the indicator presentation, the duration of availability of display elements in pre-recognition, iconic memory may be assessed.

In the four experiments to be reported, the first three employed a visual masking paradigm to determine the efficiency with which iconic processing occurs. The first two of these examined a wide range of ages in normal subjects; while the third compared normal and mentally retarded subjects in order to evaluate intellective effects.

These experiments indicated both age effects in normal subjects and, more significantly, a deficit in efficient iconic memory for retarded subjects. Consequently, the final experiment in this series was designed to examine the nature of this deficit in iconic memory obtained for retarded subjects. Thus, a partial report technique was used to experimentally determine the duration for which an item is retained in iconic memory as a function of chronological and mental age relative to mental retardation.

An understanding of developmental and mental retardation influences on iconic memory and processes relevant to efficient and accurate processing of information through iconic memory to identification is of particular importance for the learning process in general. Since iconic memory represents an initial stage of processing information, any inaccuracy or inefficiency at this stage will certainly detract from any subsequent processing such as short and long term memory. Thus the learning process may be severely impaired by interference or distortion originating in iconic memory. The present project is an experimental approach toward understanding the sources of interference associated with iconic memory of visual information.

METHODS, FINDINGS, AND ANALYSIS

Experiment 1. Age Effects on Backward Visual Masking (Crawford Paradigm)

Studies employing the visual masking paradigm lend support to the notion of a pre-recognition storage stage in visual information processing. Kahneman (1968) has provided a good review of the visual masking literature. Neisser (1966) has termed this storage stage "iconic memory." Of interest in the present investigation were the effects of chronological age on the speed of pre-recognition processing from the "icon." The present study employed the backward visual masking technique as a means of isolating possible age differences in iconic processes.

Certain characteristics are essential for experimental investigations dealing with developmental effects of iconic processes: 1-a wide range of ages should be examined, 2-equivalent performance among age groups in an unmasked condition should be clearly demonstrated prior to masking, 3-feedback and verbal reinforcement should be implemented to provide the motivation necessary for peak performance in all subjects, 4-a centrally-based masking paradigm, for example the Crawford paradigm, should be used rather than the peripherally-based metacontrast paradigm. Spencer (1969) has an excellent discussion of this issue. 5-data from all interstimulus interval values used should be analyzed, in order to give a complete picture of masking effects.

As it now stands, the literature in the field of visual masking still poses some basic and very important questions. For example, there has yet to be a systematic study of masking effects as a function of age; rarely have previous studies made use of other than normal adult subjects. When age has been used as a variable, it has typically been restricted to a range too small to make meaningful generalizations to broader age ranges, (e.g., Pollack, 1965, used children ranging from ages 7-10 yrs.; Spitz & Thor, 1968, employed normals with CAs of 9.92 and 15.00; and Thor, 1970 used children from first, fourth, and eighth grades).

The present study overcomes this problem by collecting data from a wide variety of age groups ranging from kindergarten children to college students of adult age. It is our belief, that in this manner, a truly accurate picture of developmental changes which appear in the susceptibility of visual masking was obtained. In addition, none of the previous 3 or 4 relevant studies have incorporated all of the aforementioned requirements. The present study employed subjects in four age groups from 5 to 23 years old and met all of the other prerequisites stated earlier.

Method

Subjects

Four groups of 15 Ss each were used. Three groups consisted of 5, 10, and 16 year-old volunteers from the Vermillion Public School System, Vermillion, South Dakota. The fourth group contained 22-23 year-old volunteers attending summer session at the University of South Dakota.

Apparatus and stimuli

The stimuli were 2 X 2 in. high resolution, black and white slide transparencies presented via two Kodak Model 800 Carousel projectors mounted one above the other. Stimuli were projected on the rear of a rectangular ground glass screen, 3 in. X 6 in. located 26 in. from the projectors. The target stimuli consisted of the black capital letters "E", "H", "K", and "X", which were presented one at a time at the center of the rectangular screen. All stimuli were viewed by the S from a distance of 46 in. The screen was at the end of a viewing tunnel which excluded all extraneous light. Each letter subtended a visual angle of .63° in height and .32° in width, while the stroke width of the lines composing the letters subtended .08°. The masking stimulus was a square grid pattern composed of criss-crossed diagonal black lines. The masking stimulus subtended a visual angle of 1.25°, and the stroke width of the individual lines comprising the pattern subtended .16° of visual angle. Binocular viewing in a darkened chamber was utilized throughout.

A Lafayette Model TAP-E Electronic Shutter attached to the lens barrel of each projector controlled both the durations and luminances of the target stimulus and masking stimulus. Durations of both stimuli were set at 8 msec., and the luminance of the target stimulus and masking stimulus were set at 4.3 mL. and 104.4 mL., respectively. Interstimulus intervals were controlled by a Hunter Decade Interval Timer.

Procedure

Testing for each S was carried out in a single experimental session. The initial phase consisted of: (1) a visual acuity test utilizing a form recognition eye chart, and (2) the presentation of 20 unmasked trials utilizing the target stimulus alone. Subjects were instructed to call out the letter as they saw it or to guess if they did not know. Only Ss with at least 20/30 binocular vision (corrected or uncorrected) and at least an 85% correct recognition rate on 20 unmasked trials were included in the study. The next phase of the experiment involved masking trials. During a given session a total of seven interstimulus intervals were employed (0, 25, 50, 75, 100, 125, and 150 msec.). Additional trials involved concurrent presentation of target and masking stimuli. There were twenty trials involving concurrent presentation and twenty at each interstimulus interval, yielding 160 trials per session. An exception to this was in the kindergarten group where only 120 trials (15 under each condition) were presented to each S in an attempt to reduce any possible effects brought on by fatigue, boredom, and loss of concentration. The trials were presented in blocks of 40 with short rest periods between blocks. The presentation order of interstimulus intervals was randomized, as was the order of presentation of the letters, with the following constraints: (1) a given interstimulus interval could not occur more than two times in succession; (2) a given letter could not appear more than two times in succession; (3) identical interstimulus interval and letter combinations could not follow one another; (4) all letters appeared equally often for each interstimulus interval. Presentation order of blocks of trials was partially randomized between subjects.

A typical trial was as follows: After setting the appropriate interstimulus interval, the experimenter lit a "ready" light located just above the viewing screen. The _S_, when ready, initiated a trial by depressing a telegraph key which extinguished the ready light. After approximately a 2 sec. delay, the _E_ activated the interval timer, which in turn activated the electronic shutters so that the _S_ was presented with the target stimulus and the masking stimulus. The _E_ provided immediate feedback to the _S_ after his response, telling him if he was correct, or, if he was in error, what letter had actually appeared. In addition, verbal reinforcement for correct responses was employed. Each response was recorded by the _E_, who then set the next interstimulus interval, advanced the carousel projector to the next target stimulus, and proceded with the next trial. The intertrial interval was approximately 10 sec. Experimental sessions lasted approximately 1 hour.

Results

Data from the present study are presented in Figure 1. Percentage of correct responses for the four age groups is plotted as a function of interstimulus interval(ISI). Unmasked performance levels are also indicated.

An analysis of variance performed on the accuracy data for the unmasked condition yielded a significant groups effect, $F\ (3,56)=3.098$, $p<.05$. Each analysis is summarized in a separate table presented in the appendix. Subsequent Tukey A tests indicated that the group differences were due only to the superiority of the 22 year-old group over the 5 year-old group ($p<.01$). However, this effect was hardly appreciable since the greatest difference between the two groups being 5% (97 vs. 92%).

An analysis of variance performed on the data for all groups at the 8 ISI values from concurrent to 150 msec. showed significant main effects for Groups, $F\ (3,56)=25.60$, $p<.001$, and ISIs, $F\ (7,392)=266.38$, $p<.001$, as well as, a significant interaction effect, $F\ (21,392)=10.60$, $p<.001$. In other words, all groups demonstrated increased accuarcy with increased ISI. More importantly, group effects occurred at longer ISIs.

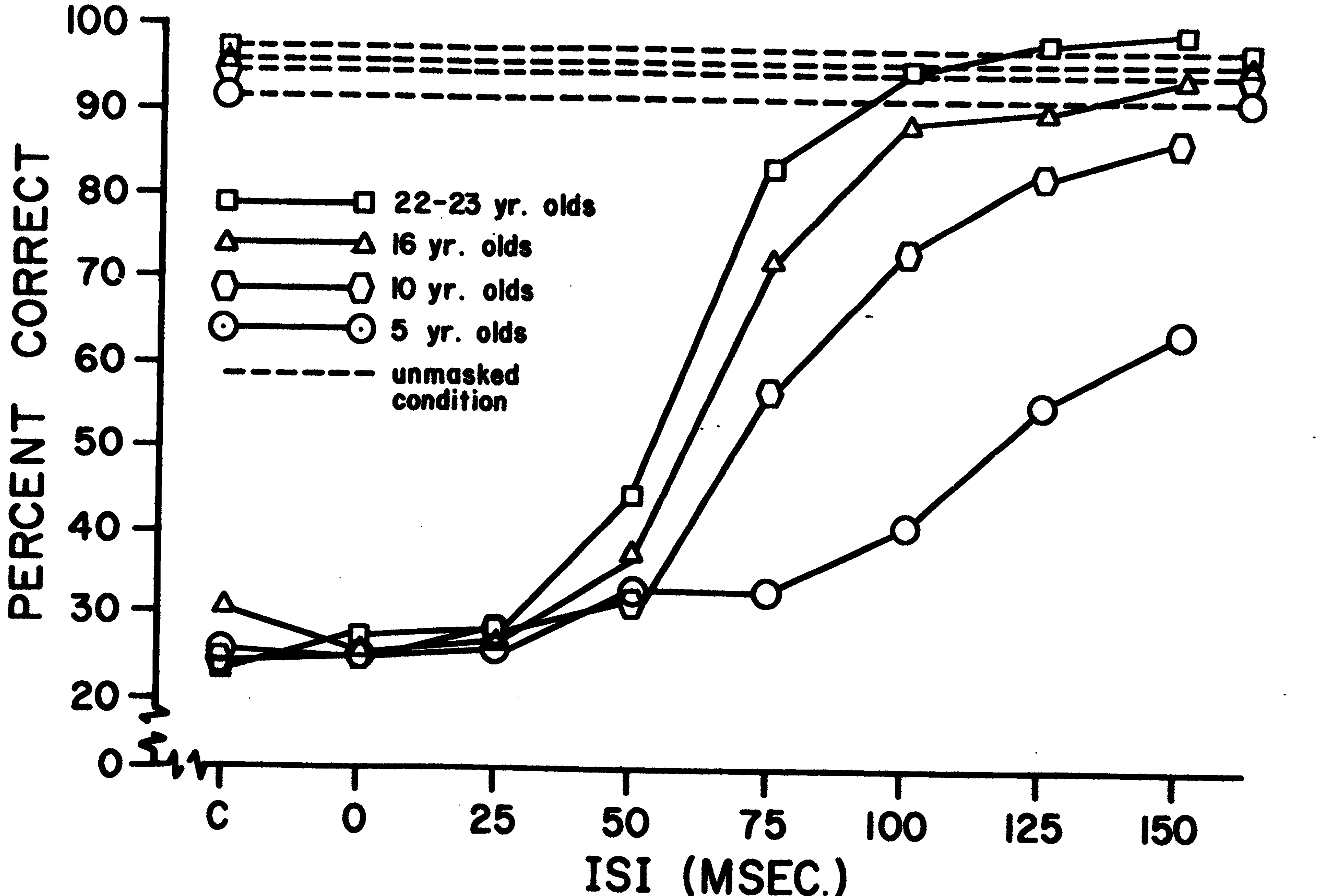

Fig. 1 Masking Functions for the Age Groups in Exp. 1.

Subsequent Tukey A comparisons generally supported the significantly ($p<.01$) more accurate performance of older subjects at ISIs of 75 msec. and longer. As shown in Table 1, these comparisons revealed a number of significant group differences at the 75 msec. ISI. Furthermore, the 5 year-old group was significantly below all other groups from 75 msec. out to 150 msec. (ps<.01). Similarly the 10 year-old group was significantly below the two older groups from 75 to 125 msec. (ps<.01).

Table 1

Summary of Tukey A Pair Comparisons on All Group Differences at ISI = 75 msec.

Groups	Mean % ($\bar{X}$)	$\bar{X}$-33.06	$\bar{X}$-56.33	$\bar{X}$-72.32
22 yr.	83.33	50.27**	27.00**	11.01
16 yr.	72.32	39.26**	15.99*	
10 yr.	56.33	23.27**		
5 yr.	33.06			

(** = $p<.01$, * = $p<.05$)

Of additional interest, detailed response profile analyses were performed on the data. Chance performance specific to each age group was examined for possible effects of any response bias. For example, regardless of which target letter was presented, did the <u>S</u> respond with one letter more frequently? A Chi Square analysis was performed on the percentage of responses of each letter for each group at ISIs where performance was not significantly above chance level. The analysis was not significant ($p<.30$), indicating no significant relation between a particular letter response and age groups. Furthermore, the group response data were analyzed for ease of letter recognition at ISIs in which significant above-chance performance occurred. A Chi Square analysis of these data was also not significant ($p<.60$). In words, no significant relation existed between an individual target letter and age group.

Discussion

The present finding that age and iconic processing efficiency are directly related is consistent with the results of Spitz and Thor (1968). The methodology of the present study included a wide range of ages, immediate feedback, a centrally-based masking paradigm, and an analysis of all ISIs; techniques not applied in most previous investigations.

Further discussion of these results are best postponed until the results of Exp. 2 have been described. The data from Exp. 2 represent an extension of the present age range.

Experiment 2: Adult Age Effects on Backward Visual Masking (Crawford Paradigm)

This experiment extended the findings of Exp. 1 by employing older subjects than in the previous study. In all other respects, it was identical to Exp. 1.

Method

<u>Subjects</u>

Three groups of 15 subjects each were constituted of volunteers from the Vermillion area, including students, faculty, and staff of the University of South Dakota. The three groups had mean ages of 18, 35, 55 years with a 2-year range in the older two groups.

<u>Apparatus, stimuli, and procedure</u> were identical to Exp. 1.

Results

Percentage of correct responses for the three age groups as a function of interstimulus interval are presented in Figure 2. Also indicated are the unmasked performance levels for all groups, which were not significantly different.

An analysis of variance performed on the accuracy data for all groups at the 8 ISI values from concurrent to 150 msec. revealed a significant main effect for Groups, $F\ (2,42)=3.558$, $p<.05$, and ISI, $F\ (7,294)=437.659$, $p<.001$, with no significant interaction. Subsequent Tukey A comparisons showed the only significant group difference was the superiority of the 18 year-old group over the 54-56 year-old group ($p<.05$). However, this effect was hardly appreciable since the greatest percentage difference between the two groups was 11% (92 vs. 81%) which occurred at the 75 msec. ISI.

Discussion

The results of Exp. 2 have extended the age ranges evaluated in Exp. 1. Clearly consistent with the previous study, the slightly reduced level of accuracy exhibited by the oldest group may reflect a small decrease in iconic efficiency which develops past middle age. Nevertheless,

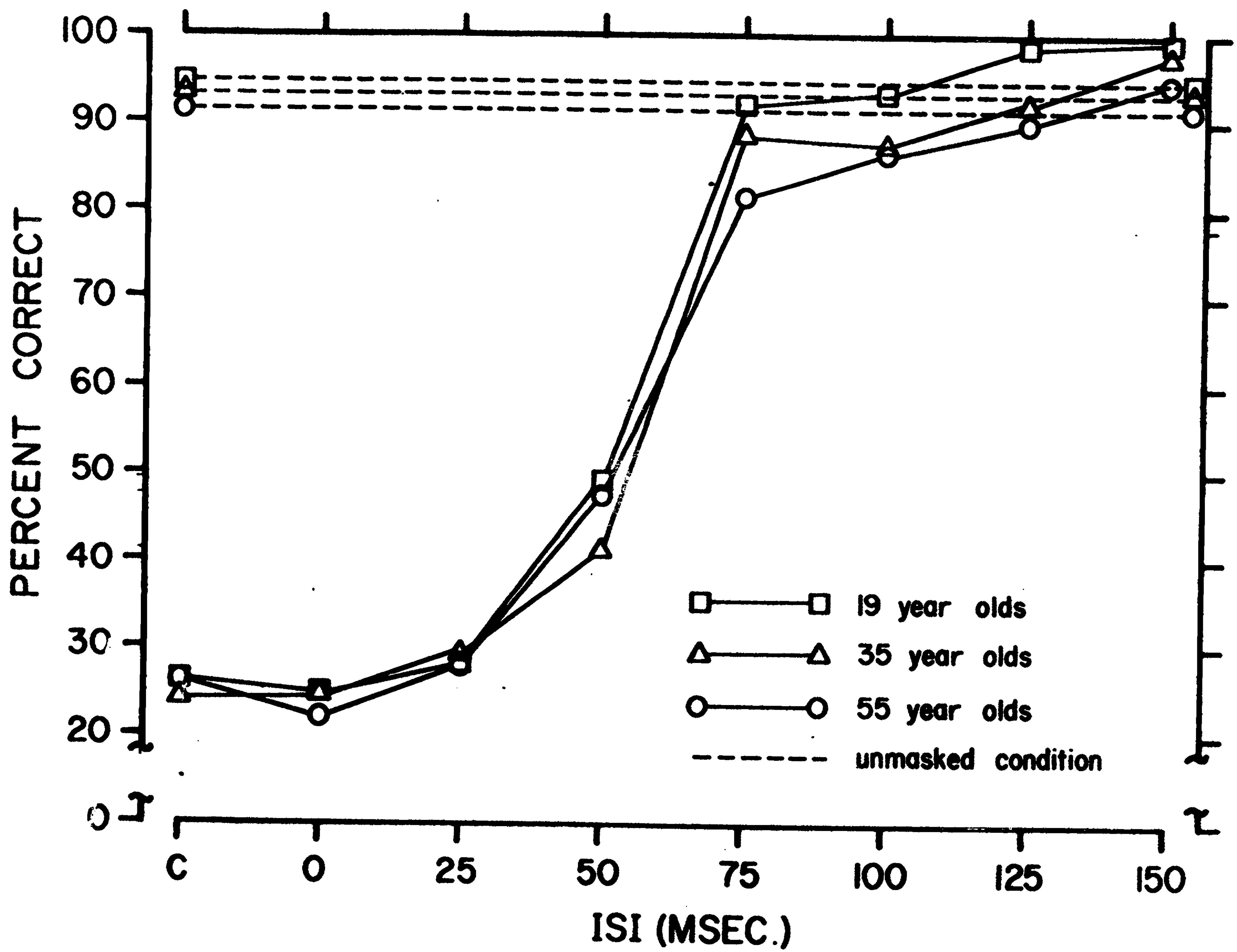

Fig. 2. Masking Functions for the Age Groups in Exp. 2

the overall relationship is one of increasing iconic memory efficiency, i.e., recognition speed, with older subjects. This increasing trend appears to level off after adulthood (near 18 years of age).

Although the present results do not directly indicate what factors are responsible for this age effect in iconic processing, the effect, itself, is most suggestive. One obvious possiblity is that accumulated experience increases iconic efficiency. Such an environmental effect would be supported by practice effects or training procedures for iconic memory. This line of research needs to be developed both for the practical applications and the theoretical significance of environmental contribution to the current age effects. Further research will be required to extend our knowledge in this regard.

One methodological point needs some discussion. Originally, the suggestion was made that equivalent performance among age groups in an unmasked condition should be clearly demonstrated prior to masking effects. Strictly understood, the masking effects must be evaluated against baseline group differences, or lack of them, in unmasked conditions. Thus, increased group differences from unmasked to masked conditions, i.e., an interaction, would be sufficient to implicate iconic memory processes in the obtained age relationship. Such a strategy allows the logical elimination of other perceptual or sensory factors as being solely responsible for the current findings. Thus the unmasked differences between the 5 yr. old and 22 yr. old groups were too small to account for the larger differences obtained during masking.

Experiment 3: Forward and Backward Masking with Normal and Retarded Subjects

There are several different paradigms of stimulus presentation which can be employed using the visual masking technique. The method utilized in the present study involved the application of the MS to the retinal area immediately surrounding, and including, the area stimulated by the TS. This procedure produces a type of masking which is most often referred to as the Crawford Effect, since it was first systematically used by Crawford in 1947 (Citation after Raab, 1963). Depending upon the sequence of the TS and MS, two masking effects can be elicited: 1) Backward masking is a reduction in the visibility of the TS when the MS follows the TS; 2) Forward masking is a reduction in the visibility of the TS when it is preceded by the MS.

The present study made use of a pattern mask comparing forward and backward masking between RS and normal subjects(NS). The rationale for so doing was that any differences in susceptibility to masking effects between RS and NS could be attributed, at least in part, to differential functionings of central mechanisms between subjects. Since no previous study has been conducted concerning the differential performance between RS and NS on both forward and backward masking tasks, no predictions along these lines were advanced other than to suggest that RS would generally be more susceptible to masking phenomena of both types.

The study described below was undertaken primarily for two reasons. The first one has already been mentioned namely, that while backward masking has received some attention using retarded individuals as subjects, no comparisons of forward and backward masking functions between NS and RS have yet been attempted. Secondly, it was felt that rigorous control of the MA variable would allow for some further speculations as to the nature of iconic processing between groups of subjects differing in "intellectual ability." For example, over all differences between groups should indicate differences in the degree of susceptibility to masking. In line with previous findings, such as Spitz and Thor (1968) and Thor (1970), it was predicted that ECA normals would be less susceptible to masking effects than either EMA normals or RS.

Furthermore, if RS are indeed significantly slower in processing information out of the icon, such a deficit should be reflected in longer ISIs at which masking effects still predominate for the RS than for their normal counterparts. Thus, EMA subjects and RS should be susceptible to masking effects for significantly longer ISIs than ECA subjects. Such a finding would underscore the importance of adequate MA for "correct" iconic processing and perception of stimulus events. In addition, information on the symmetry question with respect to forward and backward masking was gathered under conditions which have produced asymmetry with NS previously. It was anticipated that forward masking sequences would produce greater interference effects than the backward sequences for all groups.

To test these hypotheses, a three-factor design was employed involving three groups of subjects (RS, EMA, ECA), two conditions of masking (forward and backward), and eight ISI values (concurrent presentation of the TS and MS, along with ISIs of 0, 25, 50, 75, 100, 125, and 150 msec.).

Method

Subjects

The Ss were 20 mildly retarded adolescents (the RS group) from the Brainerd State Hospital in Brainerd, Minnesota; 20 normal children matched to the mental age of the retarded subjects (the EMA group); and 20 normal adolescents matched to the chronological age of the retarded subjects (the ECA group). The normal subjects were drawn from the Vermillion, South Dakota, public school system. Matching of the RS and EMA groups was based upon subject responses to the Peabody Picture Vocabulary Test (PPVT) (Dunn, 1959) which was administered prior to actual testing. Matching of the EMA and ECA groups to the RS group was accomplished using a criterion of plus or minus three months for tested mental age or calculated chronological age, respectively. Group characteristics are delineated in Table 2. Only RS whose deficiency was classified as "familial" were included as subjects in the present study to preclude any possible confounding of results due to specific perceptual deficits caused by organic abnormalities. All Ss had normal or corrected to normal vision and were paid for their services.

Table [illegible]

Chronological and Mental Age Characteristics of Subjects

Group	Mean Mental Age	Range	SD	Mean Chronological Age	Range	SD
RS	9 yrs-3 mos (111.40 mos)	6-2 (74)	18.34	14-10 (187.05)	5-1 (61)	19.08
EMA	9-3 (111.45)	5-4 (64)	17.02	-	-	-
ECA	-	-	-	14-10 (178.50)	4-8 (56)	19.66

Apparatus and stimuli were identical to those used in Exp. 1.

Procedure

Testing for each S was carried out in two experimental sessions conducted on two successive days. One session consisted exclusively of backward masking trials, the other of forward masking trials. Order of presentation of experimental sessions was varied between Ss according to an ABBA sequence sequence. The initial phase of the first experimental session consisted of the presentation of 20 unmasked trials of the TS by itself. All Ss were instructed to call out the letter as they saw it or to guess if they did not know. Any Ss who could not meet at least an 85% correct recognition rate in this unmasked condition were excluded from further participation in the study. Upon successful meeting of the unmasked criterion(UMC), the next phase of the experiment was immediately begun. During a given experimental session a total of eight ISIs were employed (a concurrent presentation of TS and MS, 0, 25, 50, 75, 100, 125, and 150 msec.) with a total of twenty trials at each ISI yielding 160 trials per session. These were presented in blocks of 40 trials with short rest periods between blocks. The presentation order of ISIs was completely randomized as was the order of presentation of the letters, with the following constraints: 1) A given ISI could not appear more than two times in succession; 2) A given letter could not appear more than two times in succession; 3) Identical ISI and letter conditions could not follow one another; 4) All letters appeared equally as often for each ISI. Presentation order of blocks of trials was partially randomized between subjects.

A typical trial was as follows: After setting the appropriate ISI, E lit a ready light located just above the viewing screen. When S was ready he initiated a trial by depressing a telegraph key in front of him which extinguished the ready light. E, after approximately a 2 sec. delay, then activated the interval timer which in turn activated the electronic shutters presenting S with the TS and MS. E provided immediate feedback to S after his response telling him if he was correct or, if he was in error, what letter had actually appeared. Upon a correct response, E also delivered a penny reward to S along with a verbal reinforcement such as "correct, very good".

This payoff procedure was introduced in an attempt to maintain high incentive motivation on the part of Ss, particularly those in the RS group (cf. Siegel, 1968). Presumably, such an incentive system would be particularly effective in the RS group since members comprising this group had recently come off a highly successful token economy program where pennies had been used as the contingent reinforcer. All responses were recorded by E who then set the next ISI, advanced the carousel projector to the next TS, and proceeded with the next trial. The inter-trial interval was approximately 10 sec. and an experimental session lasted approximately 1 hr.

Results

Figure 3 shows the percentage of correct responses for the RS, EMA, and ECA groups as a function of ISI between the target and masking stimuli under both forward and backward masking conditions. Results from the Unmasked Criterion (UMC) condition are also portrayed. (A three-way analysis of variance with repeated measures was performed on the data, the results of which are summarized in the appendix.) Inspection of Figure 1 clearly shows that as the ISI between the target and masking stimuli increases beyond a certain point, percentage of target recognition also increases for all groups ($F = 351.32$; $df = 7,399$; $p < .001$). Also apparent is an ordered Groups effect at the longer ISIs in both the forward and backward conditions, with the RS group consistently exhibiting the greatest over all susceptibility to masking and the ECA group the least ($F = 39.41$; $df = 2,57$; $p < .001$). However, the analysis also revealed a significant Groups X ISI interaction ($F = 11.13$; $df = 14,399$; $p < .001$). One explanation of this interaction is that at shorter ISIs there are no observable group differences while at the longer ISIs, group differences become readily apparent. Accordingly, a Newman-Keuls post hoc procedure (Winer, 1962) revealed no significant differences between groups at 25 msec. ISI when the forward and backward conditions were combined; however, at 75 msec. the Newman-Keuls procedure confirmed that performance for the ECA group was significantly superior to that of the EMA group, which in turn demonstrated significant superiority over the RS group ($p < .01$ for all comparisons).

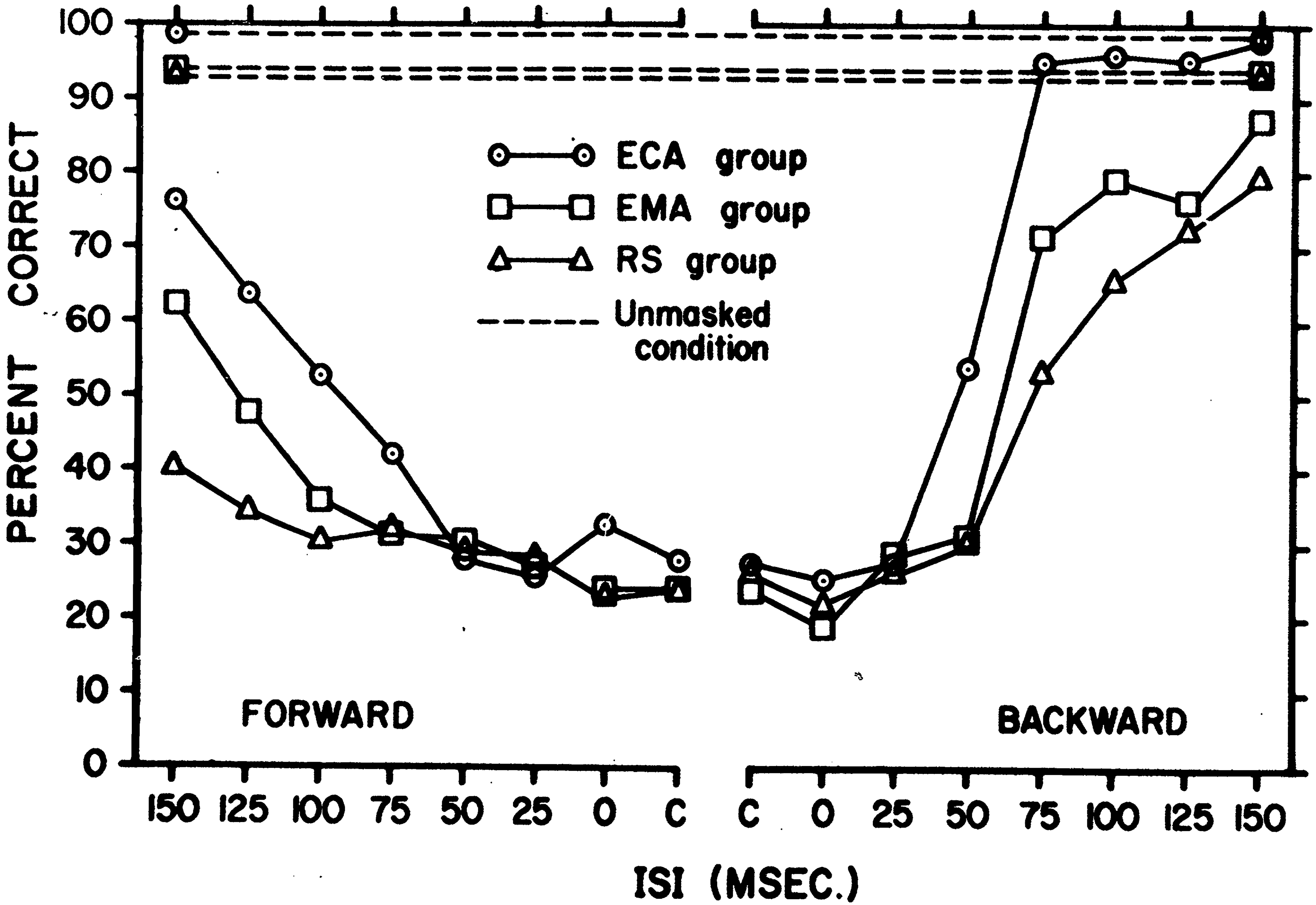

Fig. 3. Group Forward and Backward Masking Functions in Exp. 3

Further inspection of Figure 3 clearly shows that the forward masking procedure produced greater and more prolonged interference than did the backward masking sequence. Thus, the curves may be seen as asymmetrical. This observation is supported by a significant Forward-Backward effect ($f=297.25$; $df=1,57$; $p<.001$) in the basic analysis of variance. Again, however, there was a significant Forward-Backward X ISI interaction ($F=80.30$; $df=7,399$; $p<.001$). The most likely interpretation of this interaction is that at shorter ISIs, the forward and backward sequences are equally disruptive. As the ISI increases, the interference effects in the backward presentation sequence dissipate faster than in the forward sequence. Evidence for this interpretation comes from a series of Newman-Keuls tests, where group performances were pooled over the forward and backward conditions. Results indicated that at early ISIs, such as 25 msec., there were no differences between performances under the two sequences. However, at later ISIs, such as 75 msec. and beyond, performance under the backward sequence was significantly ($p<.01$) superior to that of the forward sequence, even though some masking may still have been occurring under both presentation sequences.

The analysis also yielded a significant Groups X Forward-Backward X ISI triple interaction ($F=6.10$; $df=14,399$); $p<.001$). One interpretation of this interaction is that, again, at the shorter ISIs there are no group differences but at the longer ISIs group differences do start to appear. Coupled with this interaction is the observation that group differences do not begin to emerge at the same ISI in the forward relative to the backward presentation sequence (i.e., asymmetry). Confirmation of this interpretation is provided by a series of Newman-Keuls *post hoc* procedures which demonstrated that at the 50 msec. ISI in the forward masking sequence, the groups did not significantly differ from one another. However, in the backward masking sequence at 50 msec. ISI, the ECA group was clearly and significantly ($p<.01$) superior to both the RS and EMA groups, which did not differ significanlty from one another.

Discussion

The present investigation examined the nature of visual masking, and thus iconic processing, between groups of subjects which differed in "intellectual" ability.

As evidenced, RS were generally more susceptible to visual masking effects than either their normal equivalent chronological age or, more importanlty, their equivalent mental age couterparts. Clearly these interference effects exist for longer periods of time in RS than for those in the other two groups. This is a most striking finding since the vast majority of previous studies involving chronological and mental age as variables have quite consistently demonstrated that ECA normals perform significantly better on various perceptual tasks than either EMA normals and/or RS, while these latter two groups have not differed from one another (e.g., Spitz & Thor, 1968; Thor, 1970). Such studies have suggested the necessity of adequate mental age for accurate information processing. The present study has clearly demonstrated that RS suffer from some additional impairment other than simply inadequate MA.

There are a number of alternative hypotheses which might be used to account for this significantly poorer recognition performance by the RS group. For example, Ellis (1963) has argued that the "trace" (or icon) left within the organism upon termination of the TS is less for the RS group than for either the EMA or ECA groups. Such an "insufficient icon" would lead to a decreased recognition ability and/or greater susceptibility to perceptual interference by additional stimuli on the part of retarded persons. However, this differential "iconic strength" hypothesis fails to explain one aspect of the results in the present study. The data clearly show that subjects in all groups were performing with essentially equal proficiency in the unmasked condition prior to the application of actual masking trials. This fact suggests that all groups were equal in terms of "iconic strength".

Spencer (1969) has suggested that patterned masks, in the backward masking situation, can have the effect of limiting the processing time of information stored in the icon. Eriksen and Eriksen (1971) have extended this notion to the forward masking paradigm, as well. Such a notion gives rise to a second, and perhaps more tenable, hypothesis as to the observed performance decrements by the RS group. The hypothesis is that RS process incoming stimulus information at slower rates than do NS. Thus, RS, even at the longest ISIs employed, have not reached the accuracy of either the ECA or EMA groups due to slower iconic processing rates. Moreover, the ISIs at which masking effects first show signs of significantly dissipating for RS are much longer than for those members of the other groups. Such performance deficits arise because RS have not yet completed processing the initial stimulus, be it mask or target letter, when the second stimulus arrives. This differential processing rate hypothesis is consistent with findings obtained using a variety of perceptual tasks (Spitz & Thor, 1968; Spitz, Hoates, & Holden, 1968; Thor & Holden, 1969; Holden, 1970; and Liss & Haith, 1970). These aforementioned studies have all concluded that RS do indeed process incoming stimulus information at rates <u>slower</u> than those of normal subjects.

Moreover, the present results clearly indicate that forward masking sequences generally produce greater and more prolonged interference effects than do backward masking sequences. These findings are in line with previous studies using a simple TS and a pattern mask (e.g., Kinsbourne & Warrington, 1962; Schiller & Smith, 1965; Smith & Schiller, 1966; Uttal, 1969; Zamansky, Scharf, and Brightbill, 1971). Group differences in the forward masking sequence may be readily understood in terms of the differential processing rate hypothesis offered above. Since RS presumably handle information at the slowest rate, they take longer to process the MS than do other subjects. Thus, when the target letter finally occurs, it is not readily identifiable by members of the RS group because they are still involved with the processing of the MS. The EMA group, having less intellectual development than the ECA group but <u>not</u> suffering from the additional impairment encountered by the RS group, process information at an intermediate rate. Thus, their inferior performance to the ECA group but superior performance over the RS group is interpretable.

Given that RS are indeed slower processors of visual information pursuant to recognition than normal subjects, the specific process or processes responsible for this deficiency remain to be determined. Perhaps the data of Experiment 3 are attributable to the hypothesis offered by Spitz (1964, 1966) that RS are "noisy" organisms due to disturbances in the central nervous system. Also, RS may have an icon which decays more rapidly than for others (cf. O'Connor & Hermelin, 1963; 1965). The results of subsequent research will have to develop evidence to allow for distinguishing these theoretical possibilities.

Experiment 4: Iconic Storage and Information Availability By Normal and Retarded Subjects

As noted previously, there is mounting evidence which supports the contention that there exists within the visual system a mechanism for briefly storing information after external stimulation has terminated. Partial Report procedures, as outlined above, reveal that subjects have a great many more elements available for processing before the icon fades than performance under Full Report conditions would indicate. For example, Sperling (1960) demonstrated that the ability to recall one of three rows of letters indicated by an auditory cue was far superior to having subjects report all elements of the visual display. However, Sperling (1960) also pointed out that such advantages offered by the PRT soon dissipated to performance levels no better than those obtained by the FRT, if the indicator were delayed too long. Likewise, Averbach and and Coriell (1961) demonstrated a similar decay in perceptual accuracy in reporting one of several letters if a bar indicator was delayed longer than 250-300 msec. Finally, Sheingold (1971) (citation after Haith, 1971) was able to demonstrate a developmental component in conjunction with the duration of the iconic storage mechanism. She presented complex circular arrays of geometric forms to 5-, 8-, and 11-year old children and to adults at subscan durations. At various intervals following the offset of the display, a teardrop indicator was presented randomly pointing to one of the array positions. Subjects were required to name the form which had previously occupied that position. Results showed that as the delay of the indicator increased, adults were clearly able to retrieve more information from iconic storage than were 5-year old children. Although specific results are not given, the indication is that the intermediate age groups performed in expected order fashion between the levels of performance of the adults and 5-year olds. The relative contributions of the CA and MA variables to such a relationship are impossible to assess due to their complete confounding in the design of Sheingold's experiment.

The increased number of stimuli available under PRT conditions may be attributed, at least in part, to temporal organizational properties of the icon. Eriksen and Collins (1967, 1968) have provided an elegant demonstration of such organizational properties by presenting subjects with two successive visual stimuli. The stimuli were formed by breaking up a nonsense syllable into two stimuli of random dots, neither one of which could be recognized alone as the nonsense syllable. These investigators were able to show that two independent stimulus presentations could be "combined" in such a way as to make the nonsense syllable recognizable, even when the ISI was as long as 100 msec.

The present experiment was designed to further investigate iconic storage functioning in RS and differences in iconic processing between normal and retarded subjects. No previous study had compared retarded subjects under PRT conditions. Since Experiment 3 had already provided some information as to the duration and stability of the icon, Experiment 4, utilizing the PRT as described above, offered an opportunity to verify these findings using a different experimental paradigm. Additional information was also secured as to the nature of the icon including such characteristics as differential "decay" rates in iconic storage and the relative contributions of CA and MA to stimulus processing. Comparisons between groups as to their performance on "non-indicator" trials (actually, using a Full Report procedure) established any differential group "limits" in iconic read-out before it fades. Moreover, significant differences between groups as to the ISI where "chance" performance first occurs would indicate differential <u>durations</u> of the iconic storage system. Closely allied with this duration notion is that of rate of <u>decay</u> of the icon. Significant differences in the <u>slopes</u> of performance curves between groups should be indicative of differential decay rates. (As it turns out, the answers to the duration and decay questions provide an excellent test of the trace theory proposed by Ellis, 1963, as described above.)

To answer the proposed questions, a two-factor design was employed, with three groups of subjects (RS, EMA, ECA) and five ISI values (0, 250, 500, 750, and 1000 msec.). Along with this a Full Report phase, where Ss were required to report all of the items they could, and a Concurrent phase, where the target display and indicator were presented simultaneously, were administered.

Method

Subjects

The same Ss who served in Experiment 3 also served in the present experiment. Again, all Ss were paid for their services.

Apparatus and stimuli

The apparatus and viewing conditions employed in the present experiment were identical to those used in Experiment 1. All stimuli used were high resolution black and white slide transparencies. The target display(TD) consisted of 12 black capital letters arranged in a circle, much like the numbers of the face of a clock. The external diameter of the circle subtended a visual angle of 2.0° while each letter subtended a visual angle of 0.2° by 0.1°. All of the letters of the alphabet were employed except "M" and "W". Twelve different TD patterns were utilized. The presentation of the patterns was randomized with the exception that a given TD could not follow itself in the presentation order. The orders of the 12 letters comprising the TDs were also randomized between individual displays, with the following contraints: 1) A given letter only appeared on two different TDs; 2) No letter appeared more than once on any given display; 3) No letter appeared more than once in a given location between displays. The indicator consisted of a single black arrow which pointed to one of the 12 positions occupied by the letters of the TD. The arrow subtended a visual angle of 0.5° and when presented simultaneously with the TD, was separated from the letters by a gap of 0.25°. The order of presentation of the arrows was completely randomized with the exception that an arrow could not point to the same relative position more than twice in succession. Luminance for the TDs and indicators was 0.54 mL and 4.3 mL, respectively. Duration for both the TD and indicator was constant at 500 msec.

Procedure

Testing for each S was carried out in a single experimental session lasting approximately 1 hour. Each session began with 20 simultaneous presentations of the TD and indicator. All Ss met a criterion of at least

85% correct recognition rate under these conditions. Once criterion was met, S was presented with 20 trials of the TD only. Utilizing the Full Report Technique, S was asked to recall either the top half (corresponding to positions 9, 10, 11, 12, 1, 2, and 3, on the clock) or the bottom half (corresponding to positions 3, 4, 5, 6, 7, 8, and 9 on the clock) of the display. (Due to experimental error, the RS group was inadvertently asked to report the entire 12 letter display during this phase of the experimental session.) This Full Report Phase was included in an attempt to measure the "capacity" of the iconic storage mechanism during conditions where it is subject to fading. Immediately upon completion of the Full Report Phase, S was presented with 100 identification trials which utilized the Partial Report Technique. There were 20 trials at each of 5 ISIs (0, 250, 500, 750, and 1000 msec.) between the TD and indicator. The indicator always followed the TD. Presentation of the ISIs was randomized with the exception that a given ISI could not be presented more than twice in succession. Trials were administered in blocks of 25 with short rest periods between blocks. Inter-trial interval was approximately 10 sec. Feedback regarding the accuracy of S's responses and reward procedures were identical with those used in Experiment 3.

Results

Figure 4 depicts the percentage of correct responses for the RS, EMA, and ECA groups as a function of the ISI between the target display and arrow indicator. Also shown are the results of concurrent presentation phases of the TD and indicator for all groups. As may be seen from the figure, all groups exhibited a large immediate drop in recognition accuracy when moving from concurrent presentation condition to the 0 msec. delay condition. Furthermore, all groups evidenced a general decrease in accuracy (# correct) of letter recognition as a function of increasing ISI. Moreover, further inspection of the figure reveals an ordered groups effect with the RS group consistently performing with the least degree of accuracy and the ECA group with the highest. A two-way analysis of variance on these data yielded a significant ISI effect ($F=26.79$; $df=4,228$; $p<.001$) and a significant Groups effect ($F=51.67$; $df=2,57$; $p<.001$). Application of a Newman-Keuls procedure (Winer, 1962) revealed the ECA

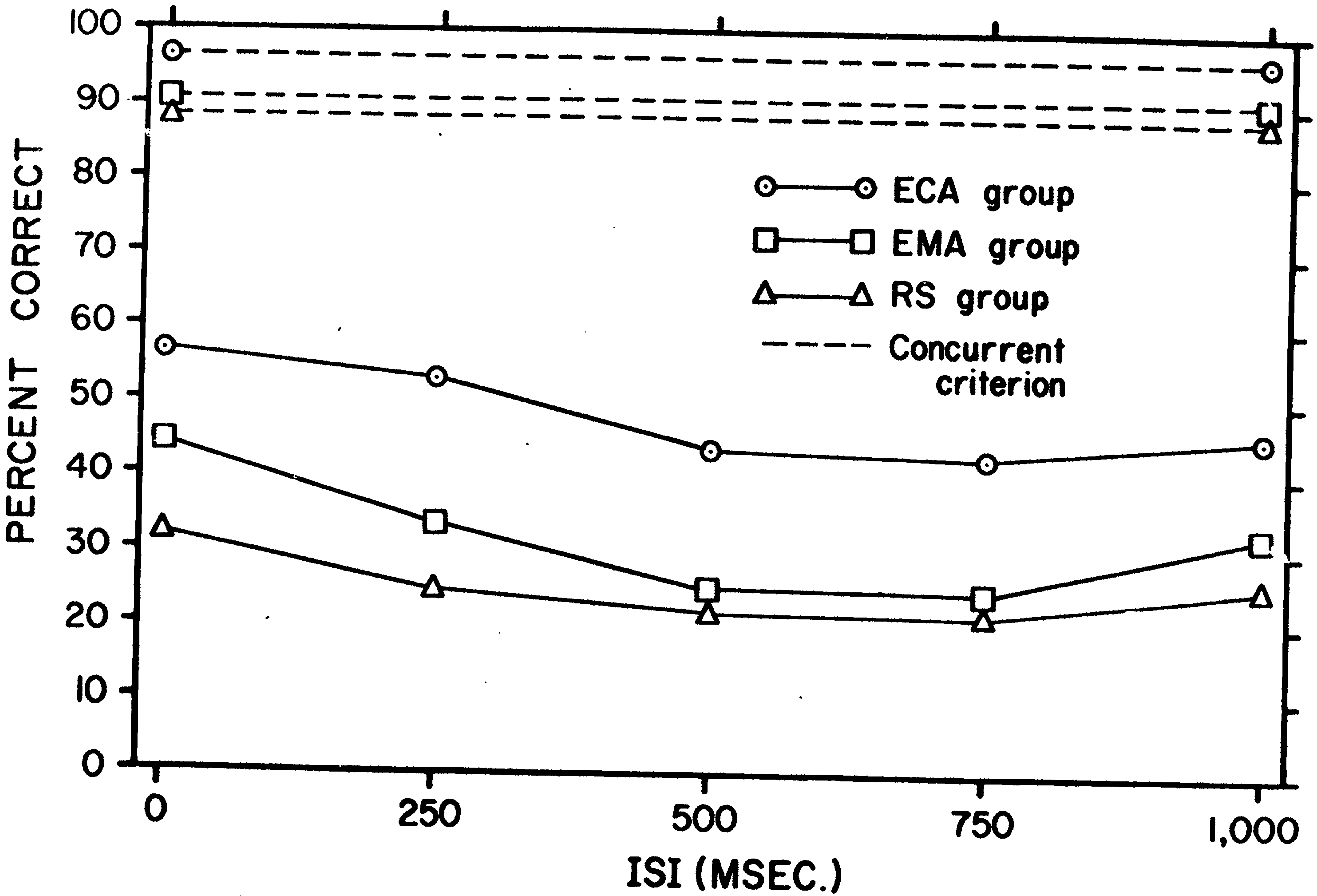

Fig. 4. Group Partial Report Performance in Exp. 4.

group to be significantly better at letter identification at all ISIs than the EMA group, which in turn was significantly superior to the RS group ($p<.01$ for all comparisons). The Groups X ISI interaction did not prove reliable ($F=1.40$; $df=8,228$; n.s.).

Table 3 gives the mean percentage correct for the EMA and ECA groups under Full Report Conditions and the two shortest ISIs where the Partial Report Technique was used. As may be noted, the ECA group again demonstrated superior ability over the EMA group in the Full Report Condition, as well as in the Partial Report Conditions. A subsequent two-way analysis of variance performed on these data confirmed the Group effect ($F=48.29$; $df=1,38$; $p<.001$) and also a Report Conditions effect ($F=10.59$; $df=2,76$; $p<.001$). Again, no significant Groups X Conditions interaction was obtained ($F=2.83$; $df=2,76$; n.s.). Subsequent *post hoc* comparisons using the Newman-Keuls procedure showed that for both the ECA and EMA groups, the 0 msec. delay condition led to significantly greater letter recognition accuracy ($<.01$) than did either the Full Report Phase or the 250 msec. delay condition, which did not significantly differ from one another.

Table 3

Group Means for Full Report Phase and Selected Partial Report ISIs

Group	Full Report Phase	Conditions 0 msec. Delay	250 msec. Delay
EMA	36.41%	44.25	33.25
ECA	46.47	56.75	53.00

Discussion

The results from Experiment 4 both confirm and extend those from Experiment 3. To begin with, the increased number of accurately reported letters from the multi-element display under the Partial Report Technique at 0 msec. ISI relative to the Full Report condition is consistent with the original PRT data (e.g. Sperling, 1960) and supports the existence of an iconic memory stage of information processing. Moreover, this effect is relatively short-lived since at 250 msec. ISI no such PRT advantage was demonstrable. Under the present experimental paradigm the functional duration of the icon seems less than 250 sec. which is in agreement with previous estimates (Sperling, 1960; 1963; Eriksen & Collins, 1967; 1968).

Of greater interest in the present design, however, are the several comparisons among the RS, EMA, and ECA groups. While all groups performed equally well under the concurrent conditions, large and differential decreases in the number of letters accurately reported occurred at all ISIs under the Partial Report Technique. Since no interaction with group differences occured as ISI increased, the deficient performance of the RS group relative to the EMA group, which in turn performed less accurately than the ECA group, may not be attributed to differences in icon decay rate. As in Experiment 3, the RS deficiency in iconic processing was demonstrated in the present results. If we pursue the suggestion made previously that RS manifest slower rate of processing incoming information, the present results may be interpreted. Specifically, the selective attention directed to an individual letter by the subsequent presentation of the arrow is delayed due to slower iconic processing. Thus, the decaying icon of the letter is attended to later by the RS group than by the EMA or ECA group. In other words, one implication of the differential processing rate hypothesis is that selective attention to iconic information is slower; thereby decreasing the availability of the rapidly decaying iconic memory of the multi-element display. Further experimental evaluations of this notion which investigate the relationship between selective attention and retardation are needed to establish to validity of the present interpretation.

Other interpretations of the present results are available. For example, the icon may have different durations for RSs than normal subjects. In addition, there may be differences in input capacity as the Full Report data might suggest. Nevertheless, considerably more information, including Full Report comparisons of RS and EMA groups, is needed before any definitive theoretical progress is to be made.

One such piece of necessary additional information would be an extension of the present experiment with two important changes in methodology. First, the values of ISI between 0 and 250 msec. must be systematically explored in order to trace the icon decay function during its major decay period. Second, conditions of information load and display clarity should be improved in order to elevate performance levels at the 0 msec. ISI value to something approximating the level obtained under concurrent conditions. This methodological feature would serve to enhance the significance of the decay function being evaluated.

In summary, the findings of Experiments 3 and 4, offer new and clear data with which to evaluate information processing problems related to retardation. Most significant of these findings is the consistent deficiency of the RS group as compared to the EMA group. The major implication this relationship is that retarded persons are plagued by iconic memory dysfunction. This impairment must be due to some additional factor other than inadequate mental age. Thus the iconic memory dysfunction demonstrated in this research may be attributed in part to retardation per se.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions. The conclusions from the present research project represent some impressive accomplishments. Several new developments concerning the factors affecting iconic memory have been made. The four studies reported employed a general methodology for investigating visual information processing which proved satisfactory for age groups ranging from 5 to 55 years of age. Moreover, this same methodology was also suitable for testing moderately retarded persons. Thus, one accomplishment of this project has been to develop and document a methodology which overcomes previous problems in studying the development and mental retardation aspects of iconic memory.

Across all studies and especially in Experiments 1 and 2, the age variable was clearly shown to influence the efficiency with which visual information is processed leading to recognition or identification. Younger subjects are much slower at pre-recognition processing, and improved iconic memory speed continues through to age 18 or so, whereupon the efficiency levels off. Some slight decrease in efficiency was also noted for subjects in the 54-56 year age range. There were no response bias or target bias tendencies which significantly distinguished the various age groups.

A major implication of the developmental trends demonstrated in this project is that children are slower to identify familiar stimuli. In addition, they are more susceptible to interference in this process by masking stimuli which occur in close temporal proximity with the target stimulus. These factors suggest that the presentation of visual information to children must be administered in such a way as to minimize inaccuracies in processing which might otherwise occur and yet not affect adults.

This project has made a major contribution to the understanding of memory dysfunction associated with mental retardation. In both Experiments 3 and 4 retarded subjects performed significantly poorer on iconic memory tasks than normal subjects matched in terms of mental age. This trend supports the conclusion that retarded individuals suffer from some iconic memory deficiency in addition to inadequate mental age development. Although more studies are needed to determine the specific nature of this memory deficiency, the data from the present project are consistent with the notion that retarded persons suffer from a reduction in processing rate for iconic information.

<u>Recommendations.</u> The recommendations ensuing from the present project are best divided into two areas: education and research. With a view to educational practice, one recommendation would be to evaluate school children early (e.g., 5-7 years of age) with regard to iconic memory ability. Thus any deficiencies would be known early in child's school career. The treatment for such deficiencies has not been determined to date: however, a recommendation along this line is that a training and treatment technique designed to improve iconic processing be developed, researched, and implemented as soon as possible.

Further research on iconic memory factors is recommended. A greater understanding of the processes contributing to the visual iconic memory dysfunction of retardates should be sought. Such research would emphasize the selective attention, processing rate and iconc duration notions developed in this report. A second line of research is also recommended. Initial investigations of iconic memory in the auditory mode which deal with developmental and mental retardation effects should be made. The techniques for studying iconic processes in the auditory mode have been recently developed (cf. Massaro, 1972). These recommendations form a research program which could significantly enrich our knowledge of iconic memory and its processes. More importantly, such understanding will contribute to our ability to deal with the information processing problems manifested by mentally retarded persons.

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APPENDIX

Summary Tables of Analyses

Table 1

Summary of Analysis on Performance in Unmasked Condition from Exp. 1

Source	DFs	Mean Square	F-Ratio
Groups	3	3.083	3.098
Error	56	.995	

Table 2

Summary of Analysis on Performance in Masking Condition from Exp. 1

Source	DFs	Mean Square	F-Ratio
Groups(G)	3	13,564.66	25.598
Error(G)	56	529.91	
ISI	7	41,057.86	266.384
G X ISI	21	1,633.48	10.598
Error ISI	392	154.13	

Table 3

Summary of Analysis on Performance in Unmasked Condition from Exp. 2

Source	DFs	Mean Square	F-Ratio
Groups	2	2.15	2.495
Error	42	.86	

Table 4
Summary of Analysis on Performance in Masking Condition fron Exp. 2

Source	DFs	Mean Square	F-Ratio
Groups(G)	2	25.77	3.558
Error G	42	7.24	
ISI	7	2003.24	437.659
G X ISI	14	4.34	0.949
Error ISI	294	4.58	

Table 5

Summary of Analysis on Performance in Forward and Backward Masking Conditions from Exp. 3

Source	DFs	Mean Square	F-Ratio
Groups(G)	2	19,262.50	39.41
Error G	57	488.81	
Forward-Backward(FB)	1	80,758.00	297.25
G X FB	2	486.00	
Error FB	57	271.68	
ISI	7	47,891.14	351.32
G X ISI	14	1,517.14	11.13
Error ISI	399	136.32	
FB X ISI	7	10,521.00	80.30
G X FB X ISI	14	799.64	6.10
Error FB X ISI	399	131.03	

Table 6

Summary of Analysis on Performance in Partial Report Condition from Exp.4

Source	DFs	Mean Square	F-Ratio
Groups(G)	2	13,894.72	51.67
Error G	57	268.92	
ISI	4	2,232.72	26.79
G X ISI	8	116.90	1.40
Error ISI	228	83.35	

Table 7

Summary of Analysis on Performance in Full Report and Selected (0,250 msec.) Partial Report Conditions from Exp. 4

Source	DFs	Mean Square	F-Ratio
Groups(G)	1	6,045.25	48.29
Error G	38	125.19	
Conditions(C)	2	909.50	10.59
G X C	2	243.00	2.83
Error C	76	85.93	