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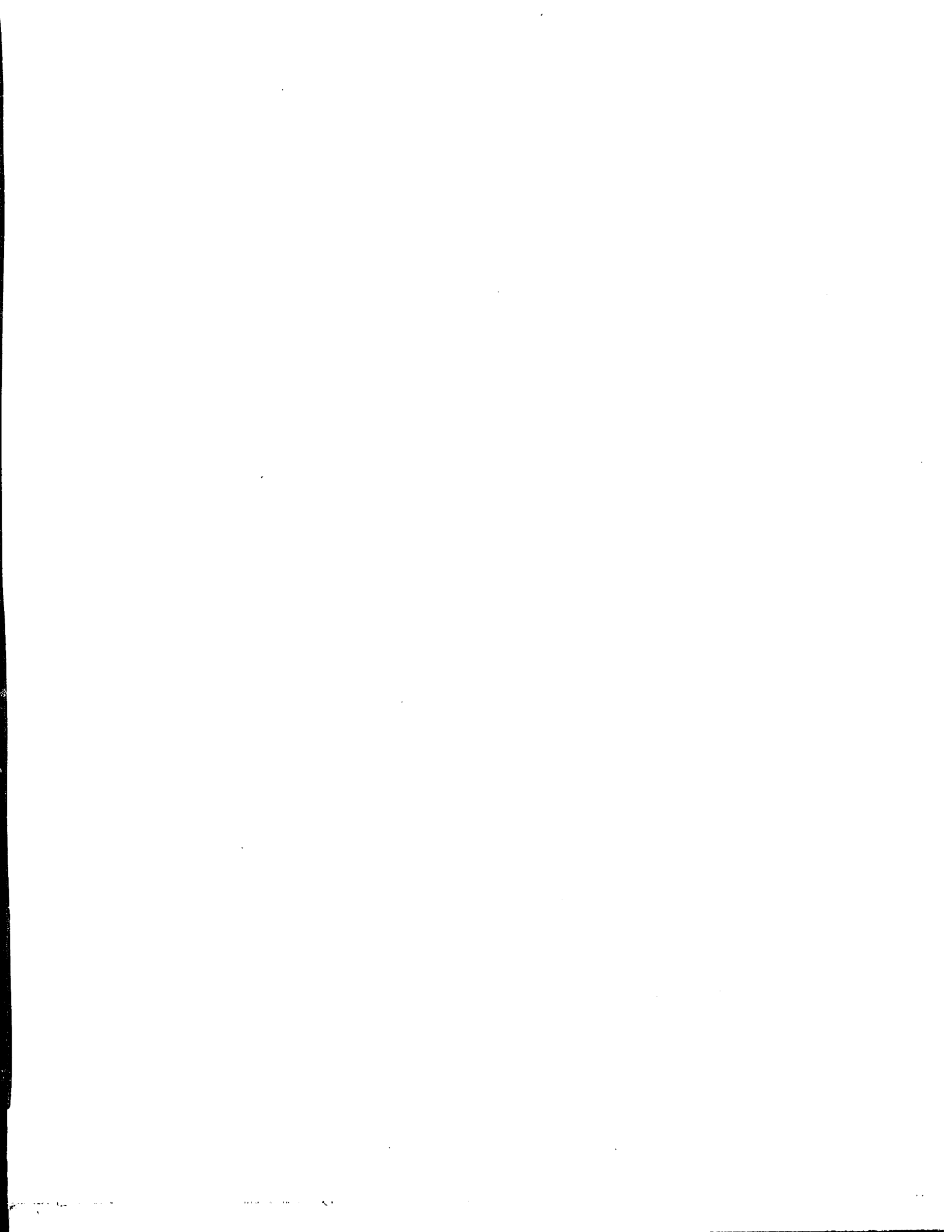
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DIFFERENCES IN ICONIC MEMORY AND PHENOMENAL PERSISTENCE:
STIMULUS ENERGY AND AGE EFFECTS

City University of New York

PH.D. 1983

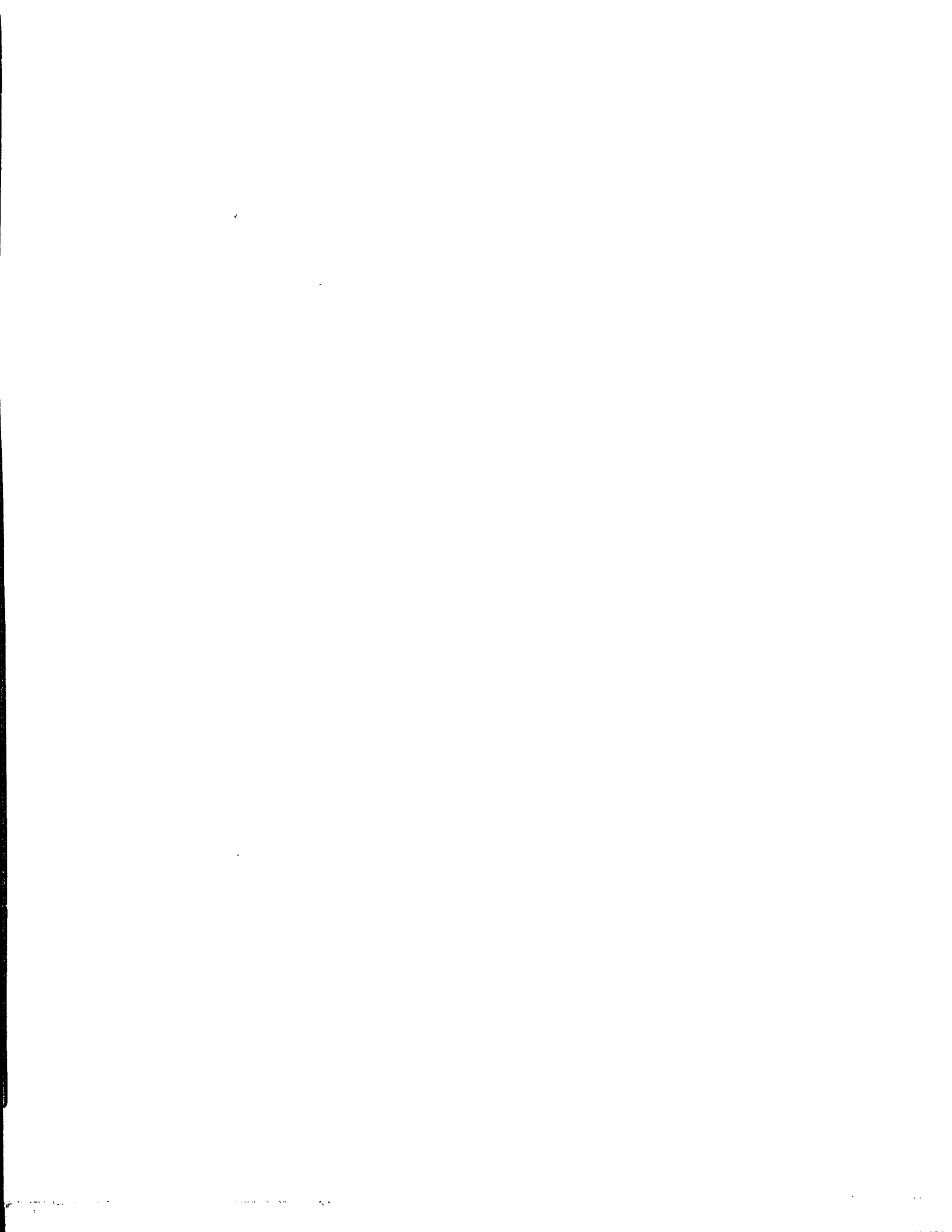
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DIFFERENCES IN ICONIC MEMORY AND PHENOMENAL PERSISTENCE:

STIMULUS ENERGY AND AGE EFFECTS

by

Philip Gerard Gasquoine

A dissertation submitted to the Graduate
Faculty in Psychology in partial fulfill-
ment of the requirements for the degree
of Doctor of Philosophy, The City
University of New York.

1983

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This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy

9/12/83
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Abstract

DIFFERENCES IN ICONIC MEMORY AND PHENOMENAL PERSISTENCE: STIMULUS ENERGY AND AGE EFFECTS

by

Philip Gerard Gasquoine

Advisor: Professor Mitchell L. Kietzman

In Experiment 1, iconic memory and phenomenal persistence measurements were compared in their duration and in their response to increases in stimulus duration (from 17 msec to 50 msec) and stimulus intensity (from 0.15 ftL to 1.5 ftL). Iconic memory, defined as visual information in a stimulus continuing to be accessible after stimulus offset, was measured with a Sperling partial-report procedure. Four columns of two randomly selected letters were presented tachistoscopically and a visual cue, presented at six intervals from 250 msec before, to 500 msec after, letter offset, designated one column for report. Phenomenal persistence, defined as a visual stimulus continuing to be visible after its physical offset, was measured with a modified Eriksen and Collins successive-forms procedure. This procedure used a cue and two complementary half-letter displays which, when superimposed spatially and temporally, formed the same display used in the partial-report procedure. The results from six subjects showed iconic memory to be of longer duration than phenomenal persistence. Iconic memory was

not significantly affected by increases in stimulus duration or stimulus intensity, whereas phenomenal persistence was inversely related (lower percentage correct) to such increases.

In Experiment 2, iconic memory and phenomenal persistence measurements in six young adult ($M = 23$ years) and six older ($M = 61.7$ years) subjects were compared. The older group produced functions of similar shape to the young adult group with a lower percentage correct. These results were at variance with previous research where older subjects had had difficulty with the partial-report procedure, yet performed better than young adults on phenomenal persistence measures. The successful performance of the older group on the partial-report procedure used here was attributed to the use of negative cue intervals which provided a higher baseline from which performance decrements could be measured. The poor performance of the older group on the successive-forms procedure relative to previous studies was attributed to the use of a more difficult letter identification task.

Especially for my parents:

Bernard William Gasquoine
June 6, 1909 - March 13, 1980

Eileen Mary Gasquoine
June 26, 1912 -

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Iconic memory and phenomenal persistence

The term "visual persistence" has been used for over a century to refer to the effect of a visual sensation being prolonged after the physical offset of the stimulus. A variety of other terms have also been used to describe this effect, e.g., iconic memory (Neisser, 1967), sensory register (Atkinson & Shiffrin, 1968), short-term visual store (Long, 1980), preperceptual memory, and sensory memory. The concept to which these terms have been applied is a rapidly decaying early information processing stage, where a visual stimulus exists in a relatively unprocessed form. By unprocessed is meant that the representation of the stimulus shares many of the properties of the stimulus itself.

A large number of different experimental procedures have been employed to measure visual persistence but performance (usually measured in terms of duration of persistence) in the different procedures has not always been the same. Three types of discrepancies have been described: (1) the duration of the process: estimates range from 100 msec to over 1000 msec; (2) the effect of increasing stimulus duration: does it increase, decrease or have no effect on the duration of the process?; and (3) the effect of increasing stimulus intensity: does it increase, decrease or have no effect on the duration of the process? These sources of dispute led Coltheart (1980a,b) to suggest

that the various experimental procedures used to measure visual persistence may be measuring differing processes.

Coltheart (1980a,b) proposed three ways in which a visual stimulus can persist: neural persistence, phenomenal (visible) persistence and informational persistence. Neural persistence refers to the physiological mechanisms subserving phenomenal persistence, so on a behavioral level Coltheart distinguished two types of visual persistence - phenomenal persistence and informational persistence.

Informational persistence, which refers to the visual information in a stimulus continuing to be accessible after stimulus offset, is measured when the partial-report procedure of Sperling (1960) is used. It is, therefore, equivalent to iconic memory, a term introduced by Neisser (1967), and the term that will be used to describe Coltheart's informational persistence throughout the remainder of this paper.

In the partial-report procedure a multi-element (usually letters or digits) display is presented tachistoscopically and followed, after a variable interval, by a cue which delimits a subset of the elements for the subject to report in their correct location. As the time interval between display offset and the onset of the cue is increased, the percentage of elements correctly recalled decreases until baseline performance is reached. This baseline performance is equal to the number of elements which can be reported when the display is flashed without a

cue to limit the subject's report (called the whole-report condition). Sperling (1960) found the average value of the whole-report baseline to be 4.3 letters recalled in their correct location, a value which did not vary with the number of letters in the display. The use of the cue enables the percentage of elements correctly reported to be more accurate in the partial-report condition than the whole-report condition, and this has been taken as evidence of the presence of a higher-capacity, rapidly decaying store -- iconic memory -- which is independent of short-term memory (a lower capacity, longer duration store).

Phenomenal persistence, which refers to a visual stimulus continuing to be visible after its physical offset, is measured when a procedure such as the successive-forms procedure of Eriksen and Collins (1967) is used. In this procedure visual stimuli (usually letters) are divided into two displays of random parts which, when superimposed spatially and temporally, form the original stimulus. The two displays are presented successively and, if the interpulse interval is brief enough, the first display persists phenomenally over this interpulse interval and the stimulus is identified. If the interpulse interval is too long, the phenomenal persistence of the first display decays before the second display appears and identification of the stimulus must be made using encoded, but no longer visible, features of the first display,

together with the visible second display, giving baseline performance (i.e., performance independent of the phenomenal persistence of the first display).

Coltheart argued that iconic memory, as measured by the partial-report procedure, and phenomenal persistence as measured by the successive-forms procedure, differ in three ways. (1) The duration of iconic memory is longer than that of phenomenal persistence. (2) Increased stimulus durations either do not affect iconic memory (DiLollo, 1977a), or slightly enhance it (i.e., give a higher percent correct, Sperling, 1960). In comparison, the duration of phenomenal persistence decreases with increased stimulus durations (Bowen, Pola & Matin, 1974; Briggs & Kinsbourne, 1972; Cohene, 1975; DiLollo, 1977b, 1980; Efron, 1970; Haber & Standing, 1970; Standing, Haber, Cataldo & Sales, 1969). (3) Stimulus intensity increments either do not affect iconic memory (Adelson & Jonides, 1980; Scharf & Lefton, 1970) or enhance it (Eriksen & Rohrbaugh, 1970; Long & Beaton, 1982). In comparison, stimulus intensity increments decrease the duration of phenomenal persistence (Allport, 1970; Bartlett, Sticht & Pease, 1968; Bowen et al., 1974; Dixon & Hammond, 1972; Efron & Lee, 1971; Haber & Standing, 1969; Hansteen, 1971; Pease & Sticht, 1965). These differences are summarized in Table 1. The inverse effect of increases in stimulus duration and stimulus intensity on phenomenal persistence were attributed by Coltheart (1980a,b) to the influence of inhibitory mechanisms within

Table 1

A comparison of Coltheart's (1980a,b) iconic memory (measured by the partial-report procedure) and phenomenal persistence (measured by the successive-forms procedure) with Long's (1980) short-term visual storage (measured by both the partial-report and successive-forms procedures).

	Coltheart (1980a,b)		Long (1980)
	<u>Iconic memory</u>	<u>Phenomenal persistence</u>	<u>Short-term visual storage</u>
(1)Duration.	300-1000 msec.	<300 msec.	<1000 msec.
(2)As stimulus duration increases.	No effect or a small direct effect.	An inverse effect.	A direct effect.
(3)As stimulus intensity increases.	No effect or a small direct effect.	An inverse effect.	A direct effect.

the visual system.

There are limits to the range of stimulus duration and stimulus intensity changes over which Coltheart considered iconic memory and phenomenal persistence to differ. When the stimulus duration is greater than about 200 msec it is questionable whether any phenomenal persistence is present at all (e.g., DiLollo, 1980; Efron, 1970). A stimulus duration of 200 msec was, however, used to measure iconic memory by DiLollo (1977a). When retinal illumination is high (greater than 1,000 Trolands) increments in stimulus intensity increase both the duration of iconic memory (Keele & Chase, 1967; Long & Beaton, 1982; Sakitt, 1976) and the duration of phenomenal persistence (Long & Sakitt, 1980; Sakitt, 1976; Sakitt & Long, 1978; 1979).

Coltheart (1980a,b) was not the first to have suggested that there is more than one type of visual persistence. Standing et al. (1969), DiLollo (1977a) and Hawkins and Shulman (1979) had all previously suggested this possibility, although Coltheart was the first to consider iconic memory and phenomenal persistence to be different. The general view had been that iconic memory and phenomenal persistence were identical (e.g. Dick, 1974; DiLollo, 1977a, 1980; Haber & Standing, 1970; Julesz & Chiarucci, 1973; Neisser, 1967). Long (1980) maintained this traditional view while attributing the discrepancies in the visual persistence literature on the effects of

increases in stimulus duration and stimulus intensity to the use of invalid procedures (i.e., visual persistence procedures which measure additional or alternative visual processes to visual persistence).

Long (1980), considering only those visual persistence studies which he judged to be valid (Eriksen & Collins, 1968; Eriksen & Rohrbaugh, 1970; Keele & Chase, 1967; Long & Sakitt, 1980; Sakitt, 1976; Sakitt & Long, 1978; 1979), concluded that the duration of short-term visual storage (Long's term for iconic memory and phenomenal persistence) increases when either stimulus duration or stimulus intensity is increased (see Table 1). Included among these studies which Long judged valid are some which used the partial-report procedure (Keele & Chase, 1967; Sakitt, 1976) and some which used the successive-forms procedure (Eriksen & Collins, 1968; Long & Sakitt, 1980; Sakitt & Long, 1978).

Hawkins and Shulman (1979) had distinguished between Type I and Type II visual persistence. Type I persistence was defined as the phenomenal duration of a visual stimulus. This definition is similar to Coltheart's definition of phenomenal persistence. The duration of Type I persistence was reported by Hawkins and Shulman to be inversely related to increases in stimulus intensity. Type II persistence was defined as "the duration of the aftereffect of the stimulus rather than ... the phenomenal duration of the stimulus itself." (p. 348). The duration

of Type II persistence was reported to be directly related to increases in stimulus intensity.

Bowling and Lovegrove (1982) attempted to reconcile the positions of Coltheart, Long, and Hawkins and Shulman by arguing that the particular experimental conditions employed by Long (and Sakitt) for most of their published work (i.e., dark background fields, dark-adapted subjects, and relatively high stimulus intensities) are optimal for the production of positive afterimages, or Type II persistence. They contend that the majority of other investigators of visual persistence have employed conditions that were unlikely to produce Type II persistence, but were likely to be measuring Type I persistence instead. Bowling and Lovegrove thus equated Coltheart's phenomenal persistence with Type I persistence, whereas Long's short-term visual storage was equated with Type II persistence. However, this analysis by Bowling and Lovegrove was post-hoc, in that the type of persistence has to be inferred after a direct or a negative stimulus duration/intensity - persistence relationship has been found. Bowling and Lovegrove did not discuss the discrepancy between Coltheart and Long concerning the relationship of iconic memory to phenomenal persistence.

Experiment 1: Stimulus energy effects

A test of the two contrasting positions held by Coltheart and Long was made in the present experiment by comparing visual persistence performance in a

partial-report procedure and a successive-forms procedure, where stimulus duration and stimulus intensity were varied. An optimal comparison was obtained by having the task of the subject, the type of stimuli, and the range of stimulus duration and stimulus intensity variations identical for both procedures. This was accomplished by adding a partial-report cue to the successive-forms procedure. The successive-forms procedure used an eight letter display presented in two complementary half-displays which, when superimposed spatially and temporally, formed the same display used in the partial-report procedure. Such a design allowed a direct comparison of the process measured by each procedure under identical stimulus conditions.

In any partial-report procedure the percentage of letters correctly reported decreases as the cue interval is increased. The duration of iconic memory has usually been estimated by reporting the value of the cue interval where performance first reached the level of whole-report performance (Adelson, 1978; Keele & Chase, 1967; Sperling, 1960). As an example, if whole-report performance was reached at the 400 msec cue interval then the duration of iconic memory was estimated as 400 msec. However, Coltheart (1980b) has noted that this method underestimates the true duration of iconic memory as cue processing time has not been taken into account.

Averbach and Coriell (1961) showed that it takes from 200 msec to 270 msec to identify (by scanning) the

position of a visual partial-report cue and apply it to the display (cue processing time). To measure this cue processing time in the present experiment it was necessary to use negative cue intervals (i.e., the cue was presented before the stimulus display). The duration of the processes (both iconic memory and phenomenal persistence) were measured from the cue interval where percentage correct performance was a maximum (suggesting optimal cue processing time) to the cue interval where performance reached baseline (whole-report performance). Two dependent measures were thus obtained for each procedure: percentage correct performance and duration.

Experiment 1A

Method

Subjects

Six subjects, three male and three female, with a mean age of 24.5 years (range of 22 to 27) were paid to participate. All subjects were college undergraduates or graduates; had English as a first language; had at least 20/30 corrected or uncorrected vision in their better eye, as measured by the Snellen Chart; and did not have any prior experience with the procedures used here.

Apparatus

A Radio Shack TRS-80 Model 1 microcomputer was programmed with Level III Basic to act as a tachistoscope. The TRS-80 has a P-4 phosphor cathode ray tube which works on the raster principle, giving a display which strobes 60

times a second. The P-4 phosphor display has a virtually instantaneous rise time and a decay time of 60 microseconds. The intensity and the duration of the micro-computer display was measured with a Pritchard Photo Research Company photometer. The raster operation limits increments in the duration of the display to 17 msec steps.

Subjects were seated with a chin-rest, 1.10 meters from the center of the computer screen in a darkened room. A small pilot light was placed above the computer screen to illuminate a sheet of paper which listed all the possible responses (14 letters), that the subject could make. Its illumination also permitted the operation of the microcomputer keyboard.

For each trial eight letters were randomly selected with replacement by the computer from a stimulus pool of the following 14 uppercase letters: B, C, D, F, G, H, J, L, P, Q, R, S, T, and Y. These are shown in their actual size in Figure 1. These 14 letters represent all the uppercase consonants that were able to be formed by using TRS-80 graphics. All vowels were excluded to prevent the formation of words. The eight selected letters were presented in the center of the computer screen in a 2x4 matrix which was white on a dark background. The contrast ratio between the display and the background was 3.67. The matrix display subtended a visual angle of 3.51 degrees of height and 4.68 degrees of width, which was similar to the visual angle used by Sperling (1960). Each letter

Figure 1: The 14 letters used as stimuli, shown in the same size as they appeared on the microcomputer screen

А
Б
В
Г
Д
Е
Ж
З

И
Й
К
Л
М
Н
О
П

subtended a visual angle of 1.17 degrees of height and 0.68 degrees of width and were viewed binocularly.

For each trial the computer also randomly selected one of the four columns of the letter display for presentation of a visual cue. This cue consisted of two horizontal bars, one of which appeared one centimeter above the top letter in the randomly selected column; the other bar appeared one centimeter below the bottom letter of the selected column. Each bar subtended a visual angle of 0.20 degrees of height and 0.68 degrees of width.

Procedure

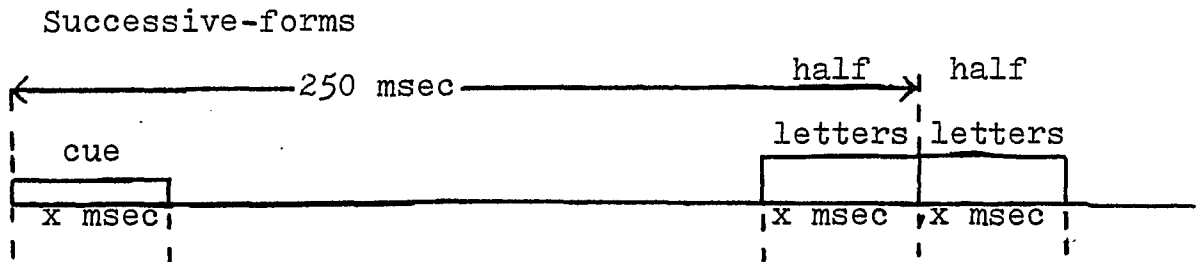
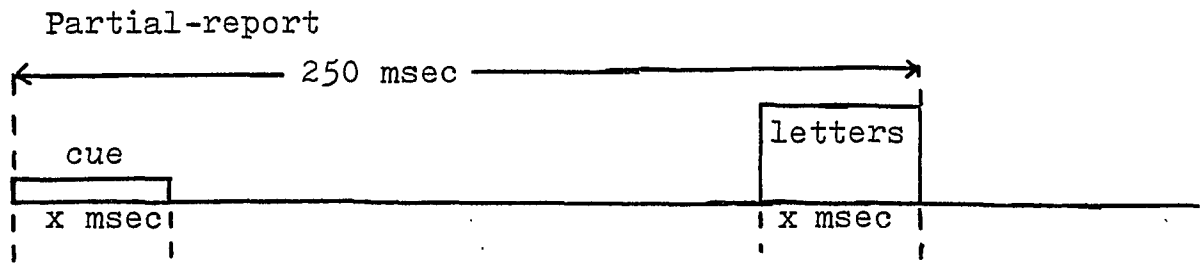
All subjects participated in both a partial-report procedure and a successive-forms procedure. Figure 2 diagrams the order of stimulus and cue presentation for the partial-report and successive-forms procedures at two representative cue intervals (the -250 msec and the 200 msec).

In the partial-report procedure the eight letter display was flashed for either 17 or 50 msec and the visual cue specified one column (two letters) for report by the subjects. The top letter had to be reported first. The visual cue had a duration equal to that of the letter display. The intervals between the onset of the cue and the termination of the letter display were -250 msec; -100 msec; 0 msec; 60 msec; 200 msec; and 500 msec (at negative cue intervals the cue preceded the display).

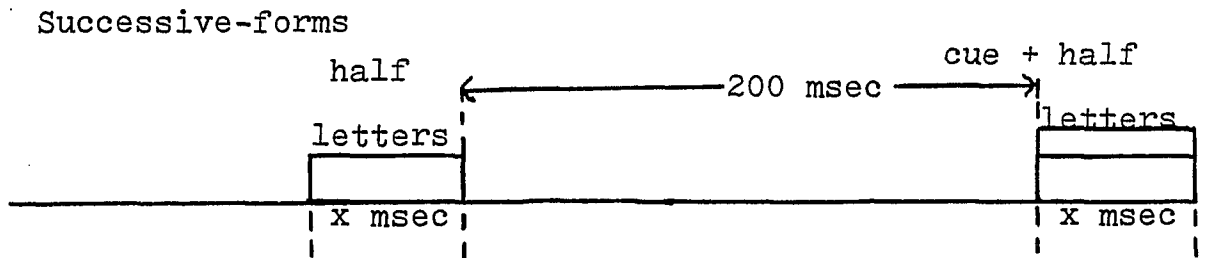
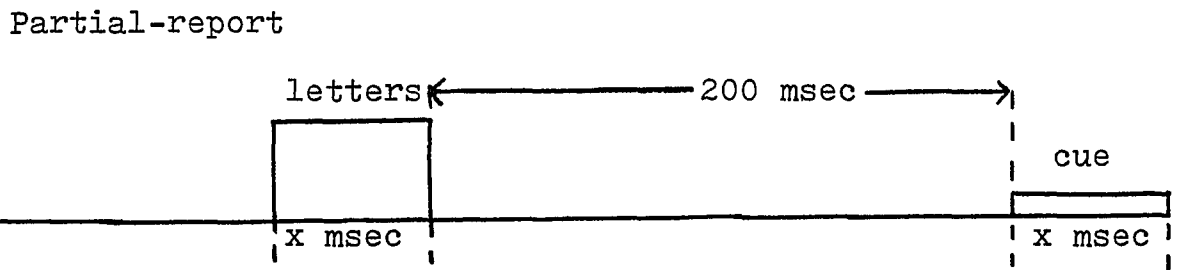
The successive-forms procedure was identical to the

Figure 2: The order of stimulus and cue presentation for the partial-report and successive-forms procedures at the -250 msec and the 200 msec cue intervals.

-250 msec cue interval



200 msec cue interval

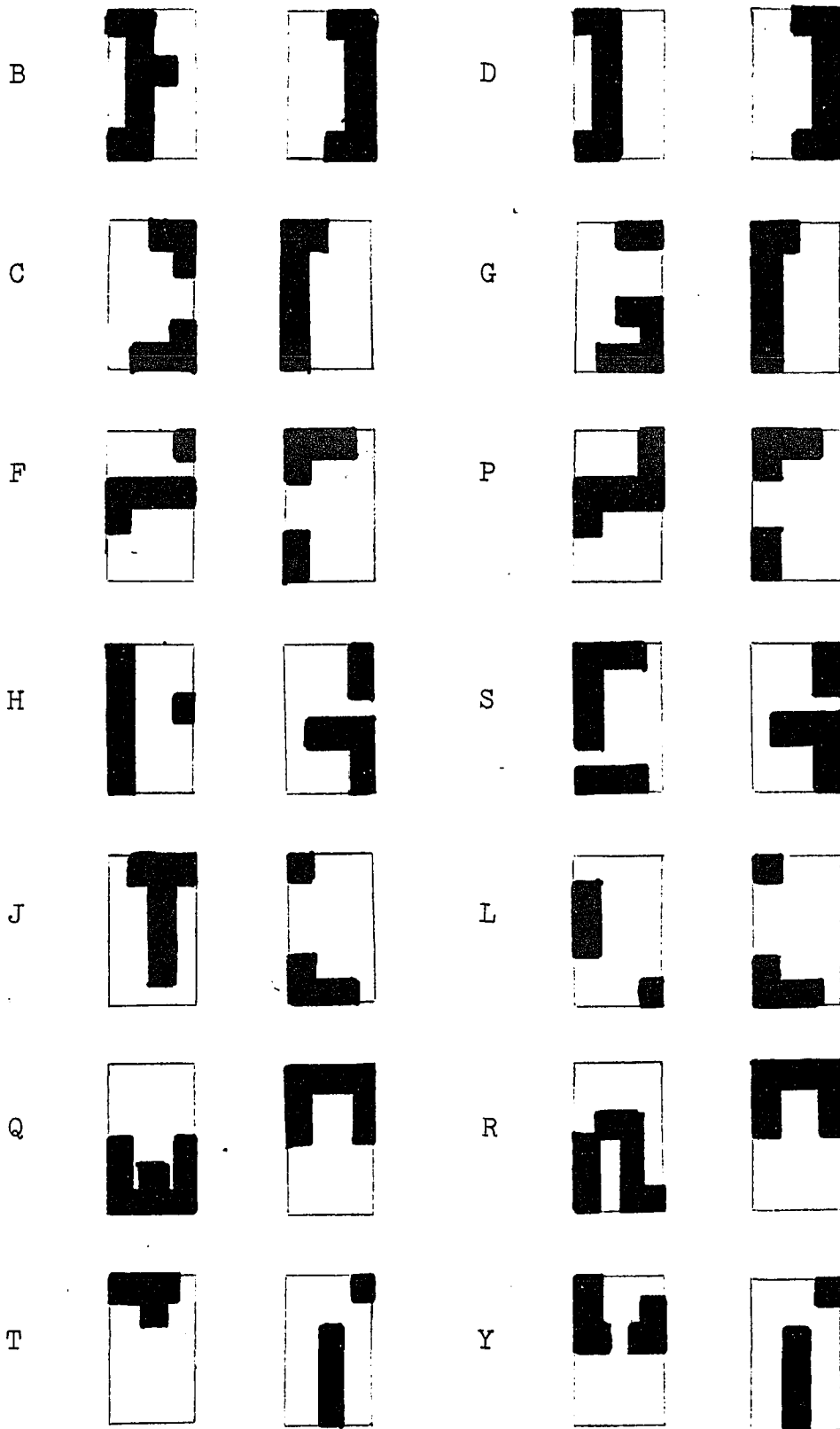


x = 50 (long duration) or 17 (short duration)

partial-report procedure except that the eight letter display was divided into two displays of eight half-letters each. When the two half-letter displays were superimposed spatially and temporally they formed the original eight letter display. At intervals between cue onset and the termination of the first half-letter display of -250 msec, -100 msec, and 0 msec, the second half-letter display immediately followed the first. At cue intervals of 60 msec, 200 msec, and 500 msec, the second half-letter display was presented simultaneously with the cue.

In order for the letters to be correctly identified (without guessing) in the successive-forms procedure the first half-letter display must persist visibly until both the cue has been processed (cue processing time) and the second half-letter display presented. If either of these two requirements is not fulfilled, identification can only be made by using encoded features from the first half-letter display, together with the visible second half-letter display. Such performance was minimized (since it does not involve phenomenal persistence) by reducing the information carried in the second half-letter display by forming the half-letters in such a way that the second half of any letter was the same as that for one other letter (see Figure 3). Thus, discrimination between B and D, C and G, F and P, H and S, J and L, Q and R, and T and Y, could only be made using the first half-letter display because for each of these pairs, their second half-letter

Figure 3: The half-letters used for the displays in the successive-forms procedure, shown in the same size as they appeared on the microcomputer screen.



displays were identical.

Both the partial-report procedure and the successive-forms procedure had the same three conditions of duration and intensity for letter and cue presentation: (1) long duration/high intensity; (2) short duration/high intensity; and (3) short duration/low intensity. The effect of increasing stimulus duration could thus be assessed by comparing performance in conditions (1) and (2), while the effect of increasing stimulus intensity could be assessed by comparing performance in conditions (2) and (3).

High and low intensities were 1.50 ftL and 0.15 ftL respectively. The low intensity condition was achieved by placing a neutral density filter over the computer screen to reduce the intensity of the letter display, the cue, and the background by one log unit. The contrast ratio between the letter display and the background was thus constant for both intensities. With the contrast ratio used no negative afterimages were present.

The long and short stimulus durations were 50 msec and 17 msec, respectively. In the successive-forms procedure the duration of the two half-letter displays together were double the duration of the single letter, partial-report display matrix. However, the sum of the areas of the two half-letter displays was the same as that of the single letter display matrix, so that, if perfect spatial and temporal energy summation was assumed, then the total

energy of the displays presented in each procedure was the same.

The order of the six combinations of procedures (2) x conditions (3) was counterbalanced among the subjects. For all combinations, the cue was presented at all six cue intervals, beginning with the -250 msec cue interval and ascending in order. Each subject had 35 consecutive trials at each cue interval, but the first 10 of these were considered as practice trials and were not included in the final analysis. The maximum possible score at each cue interval in each combination was 50 letters (2 letters x 25 trials) reported in their correct location.

Before each trial a fixation point was shown in the center of the screen. When ready, the subject pressed the spacebar to begin the trial. After the letters and cue had been presented the subject responded by typing in two letters from the 14 available for inspection. The microcomputer compared the responses with the letters displayed and the subject was informed of the percentage correct at the end of each block of five trials. Results displayed were the percentage correct for the top and bottom rows as well as for both rows together.

Before beginning, each subject had to reach a criterion of 100% performance in a block of five consecutive trials in both the partial-report and successive-forms procedures at the -250 msec cue interval in the short duration/high intensity condition. Subjects

were instructed initially to keep their eyes fixated in the central position throughout each trial and were told not to try to read the letters from left to right or to guess the position of the cue. They were also instructed to try and keep their scores for the top and bottom rows as equal as possible. The full instructions given to the subjects are in Appendix 1.

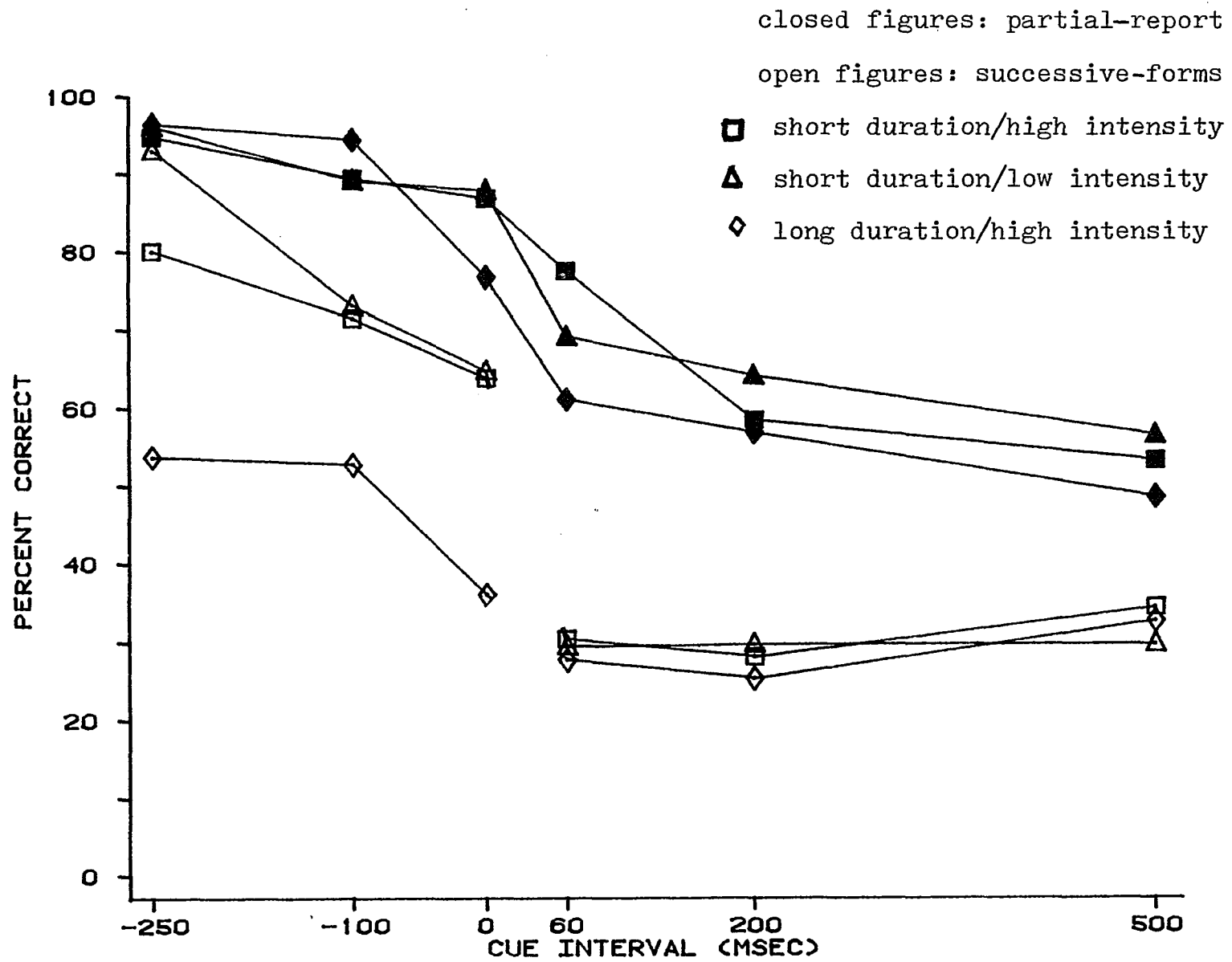
Results

Figure 4 shows the mean percentage correct performance for all six subjects in the six combinations of procedures (2) x conditions (3). The successive-forms procedure proved more difficult than the partial-report procedure except at the -250 msec cue interval in the short duration/low intensity condition, where the two procedures produced nearly the same scores (93.00% and 96.00%, respectively).

Inspection of the partial-report curves in Figure 4 shows that for all three duration/intensity conditions performance was a maximum at the -250 msec cue interval. Performance then decreased as the cue interval was increased in all three duration/intensity conditions. No single duration/intensity condition was consistently higher than any other condition over all cue intervals.

Inspection of the successive-forms curves in Figure 4 shows that for all three duration/intensity conditions performance was a maximum at the -250 msec cue interval. Performance then decreased as the cue interval was

Figure 4: Percentage correct as a function of cue interval in the partial-report and successive-forms procedures for the long duration/high intensity, short duration/high intensity, and short duration/low intensity conditions. (N = 6 subjects)



increased until the 60 msec cue interval, where the curves flattened out. From the -250 msec to the 60 msec cue interval the short duration/low intensity curve was consistently higher than the short duration/high intensity curve, which was, in turn, consistently higher than the long duration/high intensity curve. From the 60 msec to the 500 msec cue interval, there was nearly identical performance in the three duration/intensity conditions. The 0 msec and 60 msec points were not joined on the three curves to signify that from the 60 msec cue interval to the 500 msec cue interval the cue interval and the interpulse interval between the two half-letter displays were varied simultaneously. From the -250 msec to the 0 msec cue interval the interpulse interval was 0 msec.

Since the main interest was in the effect of the variables (stimulus duration, stimulus intensity and cue interval) within each procedure, the results for the two procedures were analysed separately in two 3x6 (duration/intensity condition x cue interval) analyses of variance, where all measures were repeated. Because of the large number of comparisons involved the two-tailed probability of a Type I error (α level) was fixed at .025, for all comparisons, to keep the experimentwise Type I error rate respectable. With two comparisons, however, it was not possible to use this α level, since there was no table of .025 critical values for the particular test involved (the Shaffer-Welsh test). These two comparisons,

the pairwise analysis of the overall main effects for cue interval in the partial-report and successive-forms procedures, were run at the .05 level. With these significance levels the experimentwise Type I error rate was approximately 0.50.

Partial-report procedure

In the analysis of variance of the data from the partial-report procedure (see Appendix 2) the overall main effect of cue interval, $F(5,25) = 44.58$, $p < .001$, and the duration/intensity x cue interval interaction, $F(10,50) = 30.76$, $p < .01$, were both significant.

The Shaffer-Welsch test (Ramsey, 1981) was used to analyse the significant overall main effect of cue interval to determine the longest cue interval at which performance was significantly higher than baseline performance. The Shaffer-Welsch test was chosen because Ramsey (1981) has reported that this test has the highest any-pair power of several available multiple comparison procedures.

For all three duration/intensity conditions combined, performance at the 500 msec cue interval was 52.55%, which was just below the expected baseline value of 53.75% (i.e., 4.3 letters out of 8), calculated using the whole-report data of Sperling (1960). Mean performance at the 200 msec cue interval of 59.67% was not significantly higher than the baseline value (52.55%), but the mean performance at the 60 msec cue interval (69.12%) was significantly higher, Shaffer-Welsch $.05(25)$ critical

value = 9.42. Therefore, the process operating in the partial-report procedure has a duration which lasts at least to the 60 msec cue interval.

Performance was at a maximum in the partial-report procedure when the cue interval was -250 msec (95.67%, averaged over the three duration/intensity conditions), suggesting that it took at least this amount of time to process the cue. By considering both the cue processing time (250 msec) and the longest cue interval where performance was significantly above baseline or 500 msec performance (the 60 msec cue interval), it is possible to estimate the duration of the process present in the partial-report procedure as between 310 msec (i.e., 60 msec + cue processing time) and 750 msec (i.e., 500 msec + cue processing time).

The simple main effects (see Appendix 3) for the duration/intensity condition factor in the significant duration/intensity condition x cue interval interaction showed no significant differences. This, along with the non-significant overall main effect of duration/intensity condition, $F(2,10) = 1.52$, n.s., suggests that in the partial-report procedure, increasing stimulus duration or stimulus intensity had no significant effect.

Successive-forms procedure

In the analysis of variance of the data from the successive-forms procedure (see Appendix 4) the overall main effects of duration/intensity condition, $F(2,10) =$

15.29, $p < .001$, and cue interval, $F(5,25) = 83.47$, $p < .001$, and the duration/intensity x cue interval interaction, $F(10,50) = 10.29$, $p < .001$, were all significant.

When the data from the three duration/intensity conditions were combined, performance at the 60 msec cue interval (29.10%) and at the 200 msec cue interval (27.67%), was below that at the 500 msec cue interval (32.22%), suggesting baseline performance was reached by the 60 msec cue interval. The Shaffer-Welsh test was used to analyse the significant overall main effect of cue interval to determine the longest cue interval at which performance was significantly higher than baseline (60 msec, 200 msec, or 500 msec performance). This was found to be the 0 msec cue interval (54.78%), Shaffer-Welsh .05 (25) critical value = 8.12. Thus, estimating the duration of the process present in the successive-forms procedure in the same way as for the partial-report procedure, gives 250 msec (i.e., 0 msec + cue processing time) to 310 msec (i.e., 60 msec + cue processing time).

The simple main effects (see Appendix 5) for the duration/intensity condition factor in the significant duration/intensity condition x cue interval interaction showed that there were significant differences between the duration/intensity conditions at the -250 msec cue interval, $F(2,10) = 41.49$, $p < .001$, the -100 msec cue interval, $F(2,10) = 6.08$, $p < .025$, and the 0 msec cue

interval, $F(2,10) = 19.03$, $p < .001$. The Shaffer-Welsh test was used to clarify these differences.

At the -250 msec cue interval, the short duration/low intensity score (93.00%) was significantly higher than the short duration/high intensity score (80.00%) which was, in turn, significantly higher than the long duration/high intensity score (53.67%); Shaffer-Welsh $.025^{(10)}$ critical value = 11.58. This indicates that, at this cue interval, increasing the intensity of the stimulus and increasing the duration of the stimulus had inverse effects on percentage correct performance.

At the -100 msec cue interval the short duration/low intensity score (73.00%) was not significantly higher than the short duration/high intensity score (71.34%), but both these scores were significantly higher than the long duration/high intensity score (52.67%); Shaffer-Welsh $.025^{(10)}$ critical value = 17.06. At this cue interval increasing the intensity of the stimulus had no significant effect on percentage correct performance, but increasing the duration of the stimulus had a significant inverse effect. This pattern was the same at the 0 msec cue interval, where the scores for the three conditions were, respectively, 64.67%, 63.67%, and 36.00%; Shaffer-Welsh $.025^{(10)}$ critical value = 13.90.

Top row versus bottom row performance

All subjects performed better with the top row ($\underline{M} = 68.44\%$, $\underline{SD} = 5.26$) than the bottom row ($\underline{M} = 54.31\%$, $\underline{SD} =$

8.29). This difference was significant, $t(5) = 5.32$, $p < .01$. For the partial-report procedure the ratio of percentage correct on the top row to percentage correct on the bottom row was 1.22. For the successive-forms procedure this ratio was 1.33 and for both procedures combined it was 1.26.

Discussion

These results support Coltheart's (1980a,b) contention that the process measured in the partial-report procedure (iconic memory) and the process measured in the successive-forms procedure (phenomenal persistence) are different. Iconic memory and phenomenal persistence were found to differ in their duration and in their response to increases in stimulus duration and stimulus intensity.

Iconic memory had an estimated duration of 310 msec to 750 msec, calculated with the three duration/intensity conditions combined. Phenomenal persistence had an estimated duration of 250 msec to 310 msec when calculated in the same fashion.

Iconic memory was not significantly affected by increases in stimulus duration or stimulus intensity. Phenomenal persistence was significantly reduced when stimulus duration or stimulus intensity were increased. This reduction in phenomenal persistence was measured as a decrease in the percentage correct performance.

Bowling and Lovegrove (1982) reported that with dark-adapted subjects stimulus intensities of about 25 cd/m²

(7.30 ftL) or greater are necessary for the production of the afterimages of Type II persistence. The stimulus intensities used here were well below this level and subjects were not dark-adapted so the phenomenal persistence measured in the successive-forms procedure can be viewed as Type I persistence. Since partial-report curves were obtained at these low intensity levels it is apparent that the production of Type II persistence is not a necessary requirement for iconic memory. Iconic memory thus differs not only from Type I persistence but also from Type II persistence. The results produced here show no evidence in favor of Long's (1980) contention that the same process is being measured in the partial-report procedure and the successive-forms procedure, although the possibility that Type II persistence may influence performance in both procedures at intensities above 7.30 ftL cannot be ruled out, because it was not tested here.

It is important to determine whether the experimental design used here satisfies the seven criticisms made by Long (1980) of the partial-report and successive-forms procedures.

Long made the following five criticisms of the partial-report procedure: (1) underestimation of performance: he argued that since measurement of the duration of iconic memory in the partial-report procedure has traditionally failed to include cue processing time, the amount and duration of the process has been

underestimated. This problem was avoided in this experiment by using negative cue intervals which permitted cue processing time to be measured directly.

(2) Exclusive use of stimuli consisting of letters and numbers: nearly all the studies which have used a partial-report procedure have used letters or numbers as stimuli. Long argued that conclusions from this procedure should therefore be limited to such overlearned linguistic material. This criticism places a limit on the generality of the results rather than being a problem with the procedure per se, but there are exceptions to this limitation. For example, Demkiw and Michaels (1976) obtained typical partial-report results using moving squares as stimuli.

(3) Output interference; (4) Cue anticipation; and (5) Processing strategies: it has been argued (Holding, 1970) that the superiority of the partial-report condition over the whole-report condition is due to the fewer number of responses required in the former condition (absence of output interference). Holding (1970, 1971, 1973) has also argued that the superiority of the partial-report condition over the whole-report condition could be attributable to the subject successfully guessing the position of the cue (cue anticipation). Also, it has been found that, in the absence of instructions, subjects adopt certain processing strategies, such as reporting from a multi-row display in a left-to-right and top-to-bottom manner (e.g., Dick, 1967;

Mewhort, Merikle & Bryden, 1969). Such strategies may enhance performance in the partial-report condition yet be relatively ineffective in the whole-report condition, because in the latter condition the subject must report all the letters regardless of their position.

These last three criticisms are not applicable in this experiment but are valid only if the presence of the high capacity, rapidly decaying store (iconic memory) is defined solely by the superiority of the partial-report condition over the whole-report condition. An alternative definition of the presence of iconic memory, suggested by Coltheart (1980a) and used here, is the reduction in performance as the cue interval is increased. At each cue interval the subject experiences the same output interference and guessing and processing strategies can be expected to be equally effective.

Long made the following two specific criticisms of the successive-forms procedure: (1) alternate visual processes: under this heading were included such hypotheses as that of Eriksen and Collins (1967, 1968) who suggested that 'discontinuity detectors' in the visual system may underlie performance in the successive-forms procedure. Long considered such a hypothesis detrimental to the idea that short-term visual storage is being measured in this procedure. However, the discontinuity detector hypothesis is not actually a criticism of the successive-forms procedure as a measure of short-term visual storage. It

belongs to the domain of what Coltheart (1980a,b) described as neural persistence i.e., physiological mechanisms subserving phenomenal persistence.

(2) Short-term visual storage versus short-term memory: Long argued that subjects may be able to encode features of the first half-letter display into short-term memory. These non-visible features could then be combined with the visible second half-letter display to spuriously increase performance.

Such an interpretation is most relevant to conditions with relatively long interpulse intervals. Phillips (1974) found a rapid drop in performance with interpulse intervals less than 100 msec and then a gradual reduction in performance with interpulse intervals between 100 msec and 9000 msec. The rapid decay function was judged indicative of 'sensory storage' and the gradual decay function was judged indicative of short-term memory contributions. In the successive-forms procedure used here encoding into short-term memory may have improved performance at the 200 msec and 500 msec cue intervals. Since performance at these cue intervals was relatively low compared to that at the briefer cue intervals, it can be concluded that short-term memory encoding has a very small effect on the results obtained with the successive-forms procedure.

In summary, the partial-report and successive-forms procedures used here appear to satisfy the criticisms made by Long (1980) of the traditional versions of these

procedures. Therefore, the results obtained here can be accepted as valid measures of iconic memory and phenomenal persistence.

Performance in the partial-report procedure was similar to that of previous partial-report studies. Performance was highest at the -250 msec cue interval for all three duration/intensity conditions, suggesting cue processing time was at least 250 msec. This is within the range of 200 msec to 270 msec reported by Averbach and Coriell (1961). It is possible that the optimal cue processing time for this study was slightly longer since performance never reached 100%.

Coltheart (1980a) and Dick (1974), in summarising the findings of several partial-report studies, estimated the duration of iconic memory to be about 300 msec and 250 msec, respectively, but cue processing time was not included in either estimate. If cue processing time of 250 msec is included, as in Coltheart (1980b), these estimates become 550 msec and 500 msec respectively, which are both within the range reported here (310 msec to 750 msec).

The non-significant effect of increasing stimulus duration in the partial-report procedure at intensity levels below those where Type II persistence could be produced (7.30 ftL) was also reported by DiLollo (1977a) and Sperling (1960).

The non-significant effect of increasing stimulus intensity in the partial-report procedure at intensity

levels below those where Type II persistence could be produced was also reported by Adelson and Jonides (1980) and Scharf and Lefton (1970). However, Eriksen and Rohrbaugh (1970) and Long and Beaton (1982) reported a direct effect on performance as stimulus intensity was increased.

Eriksen and Rohrbaugh (1970) used a masking version of the partial-report procedure, a technique which may test other visual processes besides iconic memory (Long, 1980), thereby creating the direct intensity effect. Long and Beaton (1982) showed an increase in partial-report performance as stimulus intensity was increased from 1.0 ftL to 3.0 ftL, but the statistical significance of this difference was not reported. Inspection of their partial-report curves shows that performance at the two intensity levels was very similar from the -50 msec cue interval (the first cue interval used) until the 300 msec cue interval. As the cue interval was increased beyond this point there were large differences in performance for the two intensity levels, but at these cue intervals performance had dropped below whole-report performance (i.e., 4.3 letters correct). When performance is below this level, processes other than iconic memory are involved, and these processes are most likely the ones responsible for the direct effect of stimulus intensity.

The successive-forms procedure had never previously been used with a cue. Studies which have used typical

successive-forms procedures have estimated the duration of the processes being measured to be about 100-120 msec (DiLollo, 1977b) or 200-300 msec (Eriksen and Collins, 1968). The duration of phenomenal persistence obtained here (250 msec to 310 msec) is at the longer end of these estimates. Coltheart (1980a) and Long (1980) have both pointed out the considerable variability in the duration of the phenomenal persistence process (short-term visual storage for Long) across studies as a result of differences in specific stimulus parameters employed.

Cohene (1975), DiLollo (1977b, 1980) and DiLollo and Wilson (1978) have reported obtaining a significant inverse effect by increasing stimulus duration in the successive-forms procedure at intensity levels below those where Type II persistence could be produced. The results obtained here show that the duration of phenomenal persistence was not changed when stimulus duration (or stimulus intensity) were increased. In all three duration/intensity conditions, baseline performance was reached at the same cue interval (60 msec). The rates of decay of the three duration/intensity conditions differed, but only because the initial registration levels (i.e., performance at the -250 msec cue interval) differed. This difference in initial registration levels reflected the inverse relationship between phenomenal persistence and increases in stimulus duration and stimulus intensity.

Cohene (1975) and DiLollo (1977b, 1980) reported

decreases in the duration of phenomenal persistence as stimulus duration was increased. The reason why no change was found in the duration of phenomenal persistence among the three duration/intensity conditions used here is that at all cue intervals where performance was above baseline (-250 msec, -100 msec, and 0 msec) the interpulse interval between the two display halves was constant at 0 msec. The three studies which reported a decrease in the duration of phenomenal persistence as stimulus duration was increased, all measured performance at different interpulse intervals. DiLollo and Wilson (1978) used a constant interpulse interval and reported that percentage correct performance, but not the duration of phenomenal persistence, decreased as stimulus duration was increased.

The significant inverse effect of increasing stimulus intensity in the successive-forms procedure at intensity levels below those where Type II persistence could be produced has not previously been reported. Eriksen and Collins (1968) reported a 'small effect upon identification performance' (p. 380) as stimulus intensity was increased from 0.93 ftL to 4.64 ftL. This effect was in a positive direction but its significance level was not reported.

The shorter duration and lower intensity stimulus parameters were increased by factors of three and ten, respectively, to give the longer duration and higher intensity stimulus parameters (17 msec to 50 msec and 0.15 ftL to 1.5 ftL). Although the ratio of energy change was

greater for the lower intensity to the higher intensity condition than for the shorter duration to the longer duration condition, the change in stimulus duration had a much larger effect on performance. Performance for the short duration/high intensity condition was significantly higher than that for the long duration/high intensity condition at the -250 msec, the -100 msec, and the 0 msec cue intervals. Performance for the short duration/low intensity condition was significantly higher than that for the short duration/high intensity condition only at the -250 msec cue interval. This indicates that for the successive-forms procedure there is no linear relationship between the energy present in the stimulus and the resulting performance.

The superiority of top row performance over bottom row performance had previously been reported by Dick (1967) and Mewhort et al. (1969) for partial-report procedures. It was obtained here in both procedures despite specific instructions to the subject to try and keep performance in the two rows as equal as possible. Top row superiority may be attributable to the reading habits of the subjects.

Experiment 1B

In Experiment 1A the results supported Coltheart's (1980a,b) contention that the process measured in the partial-report procedure (iconic memory) is different from the process measured in the successive-forms procedure (phenomenal persistence). Evidence was found for

differences between iconic memory and phenomenal persistence both in terms of the duration of these processes and in their response to increases in stimulus duration and stimulus intensity. It is possible, however, that performance in the successive-forms procedure at the 60 msec, 200 msec, and 500 msec cue intervals was made spuriously low by increasing, simultaneously, the interpulse interval between the two half-letter displays and the cue interval. At other cue intervals, the interpulse interval was constant at 0 msec. Such spuriously low performance, while not changing the effect of the stimulus duration or stimulus intensity manipulations, could result in a shorter duration estimate for phenomenal persistence than perhaps would have been produced if the interpulse interval had been held constant for all cue intervals.

In Experiment 1B this hypothesis was tested by keeping the interpulse interval between the two half-letter displays constant at 0 msec for all cue intervals.

When the successive-forms procedure was first used by Eriksen and Collins (1967), percentage correct performance (identifying nonsense syllables) and the measured duration of phenomenal persistence were both shown to decrease as the interpulse interval between the two half-letter displays was increased. In order to demonstrate that the modification of the successive-forms procedure used in Experiment 1A was similar to the original procedure used by

Eriksen and Collins it was necessary to add an additional procedure where the interpulse interval is greater than zero. The percentage correct performance in this greater than zero interpulse interval procedure and the measured duration of phenomenal persistence should both be reduced if the procedure used here and that of Eriksen and Collins are equivalent.

Experiment 1B was thus designed to address the following two questions: (1) Would the percentage correct performance in the successive-forms procedure at the 60 msec, 200 msec and 500 msec cue intervals and the duration of phenomenal persistence be increased above that found in Experiment 1A, if the interpulse interval was held constant for all cue intervals?; and (2) Would the percentage correct performance and the measured duration of phenomenal persistence in the successive-forms procedure be reduced if the interpulse interval between the two half-letter displays was greater than 0 msec?

Method

Subjects

Six subjects, three male and three female, with a mean age of 21.83 years (range of 19 to 30), volunteered for this study. All subjects were undergraduate students in a Psychology class (for which this was an official class project); had English as a first language; had at least 20/30 corrected or uncorrected vision in their better eye, as measured by the Snellen chart; and did not have any

experience with the procedures used here. As a group they differed from the subjects used in Experiment 1A in that each served as a subject and an experimenter (they worked in pairs), and were not paid for their services.

Apparatus

The apparatus used was the same as for Experiment 1A.

Procedure

All subjects participated in three procedures: (1) partial-report; (2) successive-forms (0 msec); and (3) successive-forms (50 msec). All procedures used the short duration/high intensity condition (17 msec and 1.5 ftL) of Experiment 1A. The order of the procedures was counterbalanced among the subjects.

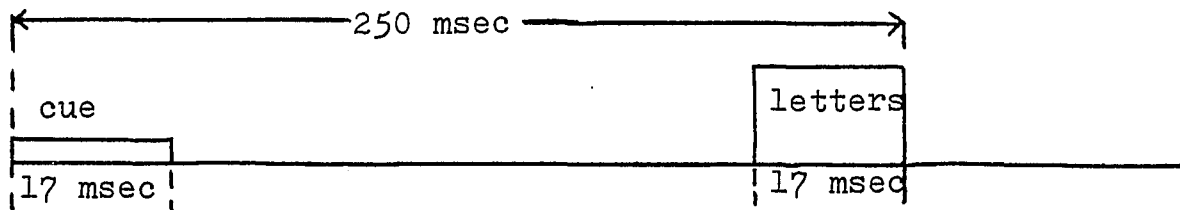
The partial-report procedure was the same as for Experiment 1A except that a -400 msec cue interval was added. The successive-forms (0 msec) procedure was the same as for Experiment 1A except that a -400 msec cue interval was added and the interpulse interval between the two half-letter displays was constant at 0 msec for all cue intervals. The successive-forms (50 msec) procedure was identical to the successive-forms (0 msec) procedure except that the interpulse interval between the two half-letter displays was constant at 50 msec for all cue intervals. Figure 5 diagrams the order of stimulus and cue presentation in all three procedures for two representative cue intervals (the -250 msec and the 200 msec).

Before beginning, each subject had to reach a

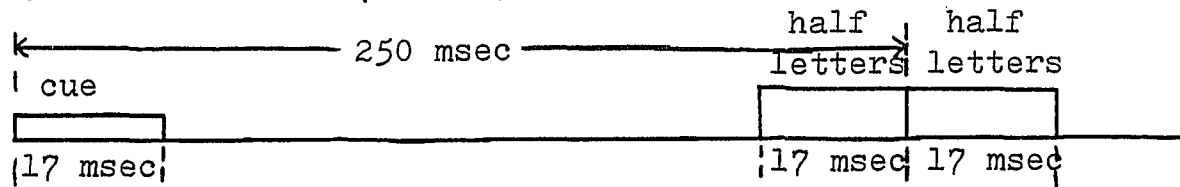
Figure 5: The order of stimulus and cue presentation for the partial-report, the successive-forms (0 msec), and the successive-forms (50 msec) procedures at the -250 msec and the 200 msec cue intervals.

-250 msec cue interval

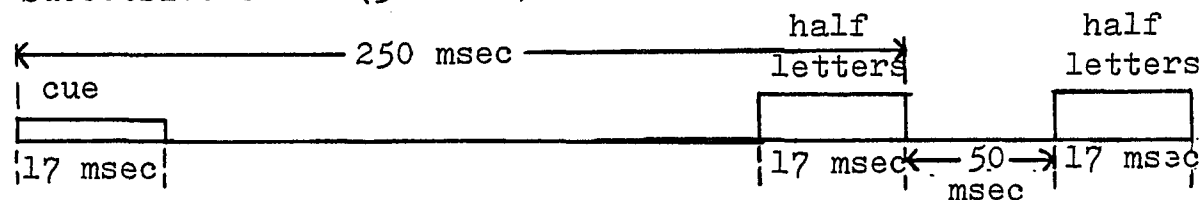
Partial-report



Successive-forms (0 msec)

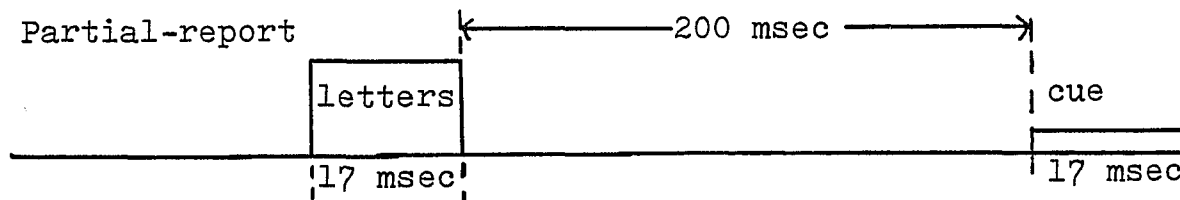


Successive-forms (50 msec)

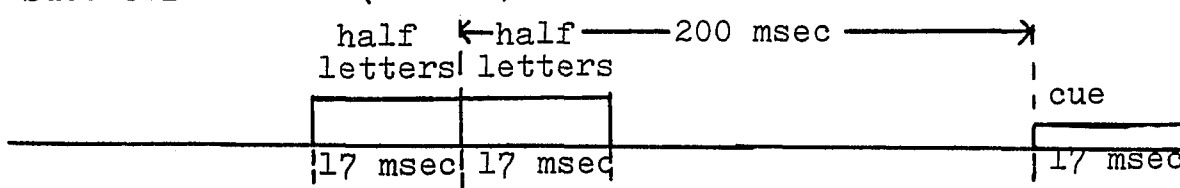


200 msec cue interval

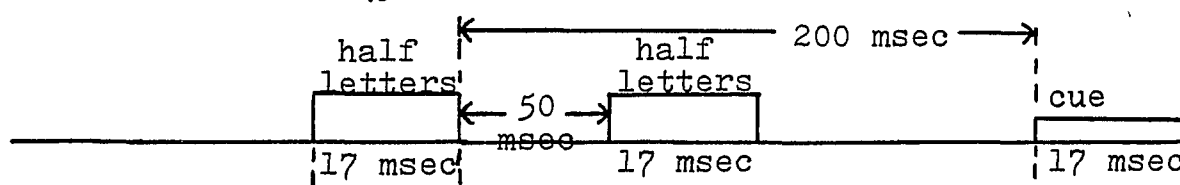
Partial-report



Successive-forms (0 msec)



Successive-forms (50 msec)



of 100% performance in a block of five consecutive trials for both the partial-report and successive-forms (0 msec) procedures at the -400 msec cue interval. The instructions and other aspects of the procedure were the same as for Experiment 1A, except that each subject called out their responses to an experimenter who typed them in on the keyboard.

Results

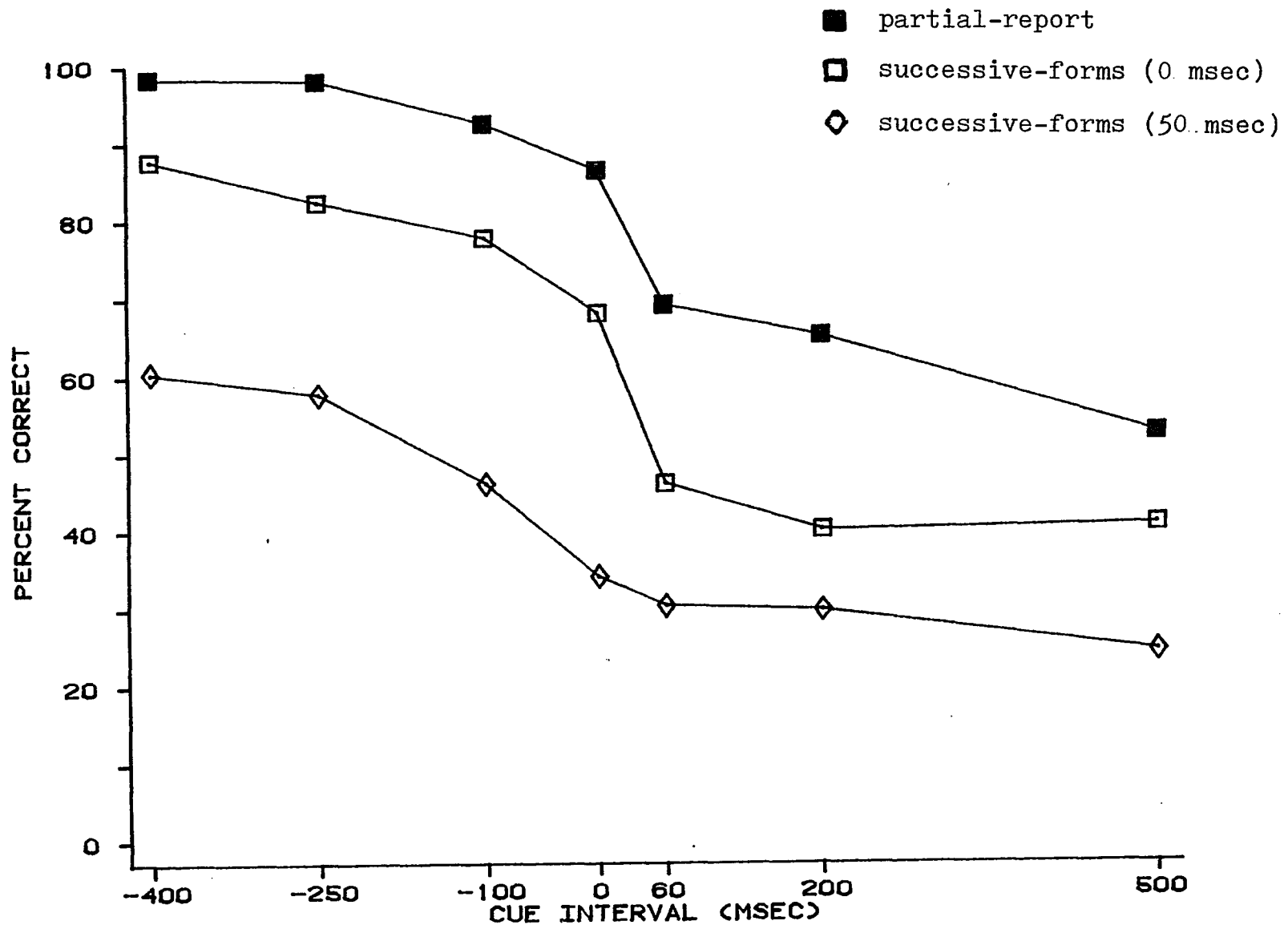
Figure 6 shows the mean percentage correct performance for all six subjects in the three procedures used. There were clear differences in difficulty between the three procedures with the successive-forms (50 msec) procedure being the most difficult at all cue intervals, the successive-forms (0 msec) procedure being of intermediate difficulty at all cue intervals and the partial-report procedure being the least difficult at all cue intervals.

Since the main interest was in determining the duration of the process operating in each procedure, the results for the three procedures were analysed separately in three 1x7 (procedure x cue interval) repeated measures analyses of variance. A .05 level of significance was used for all comparisons which resulted in an experimentwise Type I error rate of approximately 0.15.

Partial-report procedure

Inspection of the partial-report curve in Figure 6 shows that there was little difference between performance at the -400 msec cue interval (98.33%) and the -250 msec

Figure 6: Percentage correct performance as a function of cue interval for the partial-report, successive-forms (0 msec); and successive-forms (50 msec) procedures. (N = 6 subjects)



cue interval (98.00%). Performance then decreased as the cue interval was increased in a manner similar to that seen in Experiment 1A. Performance at the 500 msec cue interval (52.33%) was again just below the expected baseline of 53.75%, calculated from the whole-report data of Sperling (1960).

In the analysis of variance for the data of the partial-report procedure (see Appendix 6) the overall main effect of cue interval was significant, $F(6,30) = 35.90$, $p < .001$. The Shaffer-Welsh test was used to determine the longest cue interval at which performance was significantly higher than baseline (500 msec) performance (52.33%) and this was found to be the 200 msec cue interval (65.00%); Shaffer-Welsh $.05(30)$ critical value = 11.11. The duration of iconic memory could thus be estimated as between 450 msec (i.e., 200 msec + cue processing time) and 750 msec (i.e., 500 msec + cue processing time).

Successive-forms (0 msec) procedure

Inspection of the successive-forms (0 msec) curve in Figure 6 shows that as the cue interval increased performance decreased, except between the 200 msec cue interval (40.00%) and the 500 msec cue interval (40.67%). Comparison of performance at the 60 msec, 200 msec, and 500 msec cue intervals (46.00%, 40.00%, and 40.67%) with that obtained at the same cue intervals in the short duration/high intensity condition of Experiment 1A (30.33%, 28.00%, and 34.33%) shows that holding the interpulse

interval constant produced better performance.

In the analyses of variance for the data of the successive-forms (0 msec) procedure (see Appendix 6) the overall main effect of cue interval was significant, $F(6,30) = 37.85$, $p < .001$. The Shaffer-Welsh test was used to determine the longest cue interval at which performance was significantly higher than baseline (500 msec) performance (40.67%) and this was found to be the 0 msec cue interval (68.00%); Shaffer-Welsh $.05(30)$ critical value = 12.30. The duration of phenomenal persistence can thus be estimated as between 250 msec (i.e., 0 msec + cue processing time) and 310 msec (i.e., 60 msec + cue processing time).

Successive-forms (50 msec) procedure

Inspection of the successive-forms (50 msec) curve in Figure 6 shows that as the cue interval increased performance decreased, although differences between the 60 msec (30.33%) and the 200 msec (29.67%) cue intervals and between the -400 msec (60.33%) and the -250 msec (57.67%) cue intervals were small.

In the analysis of variance for the data of the successive-forms (50 msec) procedure (see Appendix 6) the overall main effect of cue interval was significant, $F(6,30) = 15.49$, $p < .001$. The Shaffer-Welsh test was used to determine the longest cue interval at which performance was significantly higher than baseline (500 msec) performance (24.33%) and this was found to be the

-100 msec cue interval (46.00%); Shaffer-Welsh $.05$ (30) critical value = 13.45. The duration of phenomenal persistence can thus be estimated as between 0 msec (i.e., -250 msec + cue processing time) and 150 msec (i.e., -100 msec + cue processing time).

Top row versus bottom row performance

As in Experiment 1A all subjects performed better with the top row (\underline{M} = 68.32%, \underline{SD} = 4.22) than the bottom row (\underline{M} = 56.76%, \underline{SD} = 6.89) when averaged over all three procedures. This difference was significant, $t(5) = 7.25$, $p < .001$. For the partial-report procedure the ratio of percentage correct on the top row to percentage correct on the bottom row was 1.11. For the successive-forms (0 msec) procedure and the successive-forms (50 msec) procedure the ratio was 1.20 and 1.40 respectively. For all three procedures combined it was 1.20.

Discussion

The results obtained in Experiment 1B for the partial-report procedure and the successive-forms (0 msec) procedure are very similar to those obtained in Experiment 1A. As performance in the partial-report procedure at the -400 msec cue interval (98.33%) was nearly the same as performance at the -250 msec cue interval (98.00%), subjects did not benefit from having the extra time to process the cue. The best estimate of cue processing time in this procedure is still 250 msec.

The duration of iconic memory as estimated from the

partial-report procedure was 450 msec to 750 msec. This differed from the estimate in Experiment 1A (310 msec to 750 msec) because performance at the 200 msec cue interval here was significantly higher than baseline (500 msec) performance. In Experiment 1A performance at the 200 msec cue interval was higher than baseline, but not significantly so.

In the successive-forms (0 msec) procedure, holding the interpulse interval at 0 msec for the 60 msec, 200 msec, and 500 msec cue intervals improved performance over that obtained in Experiment 1A, where the interpulse interval was the same as the cue interval. This did not, however, change the estimate of the duration of phenomenal persistence, which was still 250 msec to 310 msec.

In the successive-forms (50 msec) procedure percentage correct performance, and the duration of phenomenal persistence were lower than in the successive-forms (0 msec) procedure. Performance was 65.63% of successive-forms (0 msec) performance and the duration of phenomenal persistence was estimated to be between 0 msec and 150 msec. This result is consistent with studies using typical versions of the successive-forms procedure (e.g., Eriksen & Collins, 1967) in which increases in the interpulse interval reduced both percentage correct performance and the measured duration of phenomenal persistence.

The results of Experiments 1A and 1B taken together support Coltheart's (1980a,b) contention that the process

measured in the partial-report procedure (iconic memory) and the process measured in the successive-forms procedure (phenomenal persistence) are different. Iconic memory was found to be of longer duration (310 msec or 450 msec to 750 msec) than phenomenal persistence (250 msec to 310 msec). Iconic memory was unaffected by increases in stimulus duration or stimulus intensity, whereas phenomenal persistence was negatively affected by increases in stimulus duration and stimulus intensity. These results conflict with the traditional view that the process measured in the partial-report procedure and that measured in the successive-forms procedure are the same (e.g. Dick, 1974; DiLollo, 1980; Long, 1980).

Experiment 2

Iconic memory and phenomenal persistence in young and older adults.

Studies which have compared the performance of young and older (over 55 years) adults on visual persistence tasks have produced inconsistent results. Older adults have been found to perform better than young adults (e.g. Kline & Orme-Rogers, 1978); poorer than young adults (e.g. Kline & Baffa, 1976); and to be unable to perform the task at all (e.g. Walsh, 1975). At least some of this inconsistency can be resolved by differentiating between those studies that have used a visual persistence procedure to measure iconic memory (the partial-report procedure) and those studies that have used visual persistence procedures to measure phenomenal persistence (e.g., the successive-forms procedure). The differences between iconic memory and phenomenal persistence were outlined in Experiment 1.

Investigators of iconic memory who have used the partial-report procedure with older subjects report that these subjects are not able to perform the task if it is presented in the same way as to young adult subjects. Attempts have been made to overcome this problem by using longer stimulus durations for the older subjects.

Eriksen and Steffy (1964) found that older subjects (60 to 75 years) needed an average stimulus duration of 300 msec to reach a specified criterion level of performance

for which young adult subjects (20 to 39 years) needed an average of 116 msec. This was obtained after 40% of the older subjects but only 20% of the young adult subjects were excluded for failure to reach the criterion with stimulus durations below 500 msec.

Abel (1972) used a stimulus duration of 500 msec to compare the partial-report performance of older (60 to 77 years) and young adult (19 to 27 years) subjects. Performance decreased as the cue interval was increased for both groups, but the use of such a long stimulus duration makes it questionable to interpret the results solely in terms of iconic memory. In Experiment 1 it was shown that, with a stimulus duration of 15 msec, the visible stimulus trace decays in 250-310 msec. In the Abel experiment the stimulus is fully visible for 500 msec (assuming no phenomenal persistence), which allows the subject more time to transfer items to short-term memory than is the case with shorter stimulus durations. It is likely that performance with long stimulus durations involves a combination of iconic memory and short-term memory contributions (Walsh & Prasse, 1980).

Salthouse (1976) used a stimulus duration of 100 msec to compare the partial-report performance of older (60 to 75 years) and young adult (18 to 30 years) subjects. Older subjects performed more poorly than young even after four times as many older as younger subjects had been excluded for failure to reach specified performance criteria.

Walsh (1975) reported an experiment by Walsh and Thompson where the partial-report procedure was used with older subjects (60 to 72 years). With a stimulus duration of 50 msec these subjects had great difficulty with the task and only two of ten could reach a specified criterion. Even these two subjects showed poorer identification performance than young adult subjects.

Older subjects are known to take longer than young adult subjects to identify letters. In a backward visual masking procedure which used seven-letter strings as stimuli, Cerella, Poon and Fozard (1982) found that older subjects (60 to 71 years) could identify two letters at a rate of 35 msec per letter. Young adult subjects (17 to 25 years) could identify three letters at a rate of 27 msec per letter. Additional letters were identified at a much slower rate by both groups.

It is apparent from these results that a poorer rate of identification performance alone cannot account for the inability of older subjects to perform with the partial-report procedure, particularly if subjects are required to report only one or two letters on each trial. Abel (1972), Eriksen and Steffy (1964), and Salthouse (1976) required more than two letters to be reported on each trial but Walsh (1975) required only one letter to be reported. Since the duration of iconic memory is well in excess of 70 msec (see Experiment 1) there is ample time for subjects to identify two letters. Walsh and Prasse (1980) have

suggested that the difficulty which the older subjects experience is due largely to an inability to process the cue within the time limits of the procedure.

Studies have shown older subjects to be much slower than young adult subjects on tasks which involve visual scanning skills similar to those involved in processing a visual cue as is required in the partial-report procedure. In a study of temporal integration involving visual scanning, Eriksen, Hamlin and Breitmeyer (1970) found that older subjects (50 to 55 years) required appreciably longer exposure durations than young adult subjects (200 msec as compared to 25 msec, respectively), on a task involving identification of the quadrant containing the gap in Landolt's C. Walsh and Prasse (1980) reported an experiment by Walsh, Vletas and Thompson which showed that whereas young adult subjects could complete a combined visual search and recognition task in the time it took to do either one alone, older subjects (60 to 70 years) took the sum of the times required for each task alone.

Averbach and Coriell (1961) showed that young adult subjects took between 200 msec and 270 msec to process a visual partial-report cue and this estimate of cue processing time was confirmed in Experiment 1. It is possible to test the hypothesis of Walsh and Prasse (1980) that older subjects take longer to process the partial-report cue by using negative cue intervals greater than 270 msec. If the hypothesis is correct older subjects

should show a level of performance at such cue intervals similar to the performance of the young adults at shorter cue intervals.

Studies of age differences in visual information processing have shown older subjects to perform poorer than young adult subjects on such tasks as critical flicker frequency thresholds (McFarland, Warren & Karis, 1958; Misiak, 1947) and dark-interval thresholds (Amberson, Atkeson, Pollack & Malatesta, 1979). One hypothesis used to account for such results is that with advancing age there is an increase in the persistence of sensory traces (Axelrod, 1963; Axelrod, Thompson & Cohen, 1968; Botwinick, 1973).

If the hypothesis that stimulus persistence increases with advancing age is correct, older subjects should perform better on procedures that measure phenomenal persistence. This has been found by DiLollo, Arnett and Kruk (1982), Kline and Orme-Rogers (1978) and Kline and Scheiber (1981), with both successive-forms and phenomenal continuity procedures. Kline and Baffa (1976) and Walsh and Thompson (1978) found the opposite result with the same two types of procedures.

Kline and Baffa (1976) used the successive-forms procedure and found older subjects to perform more poorly than young adult subjects. Kline and Orme-Rogers (1978) found the opposite. Although both studies used similar versions of the successive-forms procedure there were four

differences between Kline and Baffa and Kline and Orme-Rogers, respectively: (1) the mean age of the older subjects was 55 years as compared to 68 years; (2) stimuli (words) were black on white as compared to white on black; (3) stimuli were composed of dots as compared to lines; and (4) in Kline and Baffa all subjects were equated for initial performance levels which resulted in the older subjects being given stimulus durations approximately double those of the young adult group. In Kline and Orme-Rogers stimulus durations were equal for all subjects.

Kline and Orme-Rogers favored the third difference between the two studies as contributing most to the disparate results, arguing that the use of dot stimuli in the first study disadvantaged the older subjects, who are known to have greater difficulty with "closure" than young adult subjects. However, the closure concept is vague, poorly defined and does not actually explain the results. The large inverse effect on phenomenal persistence with increases in stimulus duration as measured by the successive-forms procedure used in Experiment 1, makes it possible that the fourth difference (the difference in stimulus durations used with the older groups in the two studies) may have contributed to the improved performance of the older subjects in the Kline and Orme-Rogers study.

Walsh and Thompson (1978) used a phenomenal continuity (of letters) procedure to measure what they termed "iconic memory" (actually phenomenal persistence) in older (58 to

78 years) and young adult subjects. In the phenomenal continuity procedure the interpulse interval between successive presentations of a visual stimulus is varied until the subject reports the stimulus to be continuously visible. This interpulse interval is then taken as a measure of phenomenal persistence. In Walsh and Thompson (1978) the phenomenal persistence of the older subjects was significantly below that of the young adult subjects. This experiment was replicated by Kline and Scheiber (1981) who obtained the opposite result, which was not due to a change in the performance level of the two older groups but, rather, to a change in the performance level of the two groups of young adults. As Kline and Scheiber concluded, it appears that the phenomenal continuity procedure does not have sufficient reliability to elucidate age differences in phenomenal persistence, probably because of variability in the response criteria adopted by subjects.

DiLollo et al. (1982) compared the performance of two older groups of subjects (58 to 70 years and 71 to 83 years) with a young adult group on both a successive-forms procedure and a phenomenal continuity procedure. The successive-forms procedure was not the type originally developed by Eriksen and Collins (1967). It required the subject to report which of two simultaneously presented 5x5 dot matrices contained a missing dot. Each dot matrix was formed by the successive presentation of different dots

over time. No member of the 71 to 83 year age group completed this successive-forms procedure; the 58 to 70 year age group were able to do the task but they showed significantly longer phenomenal persistence than the young adult group. With the phenomenal continuity procedure the 71 to 83 year age group, but not the 58 to 70 year age group, showed significantly longer phenomenal persistence than the young adult group.

The evidence collected with the successive-forms procedure supports the hypothesis that older subjects have greater phenomenal persistence than young adults (DiLollo et al., 1982; Kline & Orme-Rogers, 1978). This greater phenomenal persistence was measured both as an increase in percentage correct (Kline & Orme-Rogers, 1978) and as an increase in duration of persistence (DiLollo et al., 1982). The Kline and Baffa (1976) and the Walsh and Thompson (1978) results can be discounted for the methodological problems mentioned.

In the experiment performed here, the performance of young adult and older subjects was compared using both a partial-report procedure and a successive-forms procedure. In the partial-report procedure, the hypothesis of Walsh and Prasse (1980) that older subjects take longer to process the cue was tested by presenting the cue a sufficient time before the stimulus display arrived so that the older subjects would have extra time to process it before the display arrived. In the successive-forms

procedure it was expected, based on the results from Kline and Orme-Rogers (1978) and DiLollo et al. (1982), that the older subjects would show greater phenomenal persistence.

DiLollo et al., (1982) suggested that the hypothesis that greater persistence with advancing age applies primarily to procedures involving predominantly peripheral sensory events, whereas a reduction in the rate of information processing with advancing age is a suitable explanation for age differences with procedures involving more central, higher level processes. Coltheart (1980a) views iconic memory as a more central, higher level process than phenomenal persistence. Therefore, if DiLollo et al. is correct, the older subjects should perform poorer than the young adults on the partial-report procedure, but better on the successive-forms procedure.

Method

Subjects

Two groups, each of six subjects (three males and three females), were paid to participate: a young adult group with a mean age of 23 years (range of 20 to 31) and an older group with a mean age of 61.7 years (range of 60 to 63). The older subjects were all healthy community residents (two had retired). All subjects had English as a first language; had at least 20/30 corrected or uncorrected vision in their better eye, as measured by the Snellen chart; and did not have any prior experience with the procedures used here. Two subjects in the older group were

taking antihypertensive medication but their performance was similar to other members of the group.

The two groups did not differ significantly on the reading subtest of the Wide Range Achievement Test (Jastak & Jastak, 1965). The mean Grade Score on this subtest for the young adult group was 15.77 ($SD = 1.44$) and that for the older group was 14.30 ($SD = 4.16$), $t(10) = 0.82$, n.s. The two groups also did not differ significantly on the Ravens Coloured Progressive Matrices. The mean raw score for the young adult group was 33.50 ($SD = 3.39$) and that for the older group was 30.67 ($SD = 2.66$), $t(10) = 1.61$, n.s. This mean raw score for the older group falls at the 90th percentile for people with an average age of 65 years.

Apparatus

The apparatus used was the same as for Experiment 1.

Procedure

All subjects participated in two procedures which were identical to those with the same name in Experiment 1B: the partial-report procedure and the successive-forms procedure with 0 msec interpulse interval. Three subjects in each group started with the partial-report procedure and three with the successive-forms procedure.

Before beginning each procedure, each subject was required to reach a criterion of 90% correct performance in a block of five consecutive trials at the -400 msec cue interval in the specified procedure. In the partial-report procedure the young adult group reached this criterion in

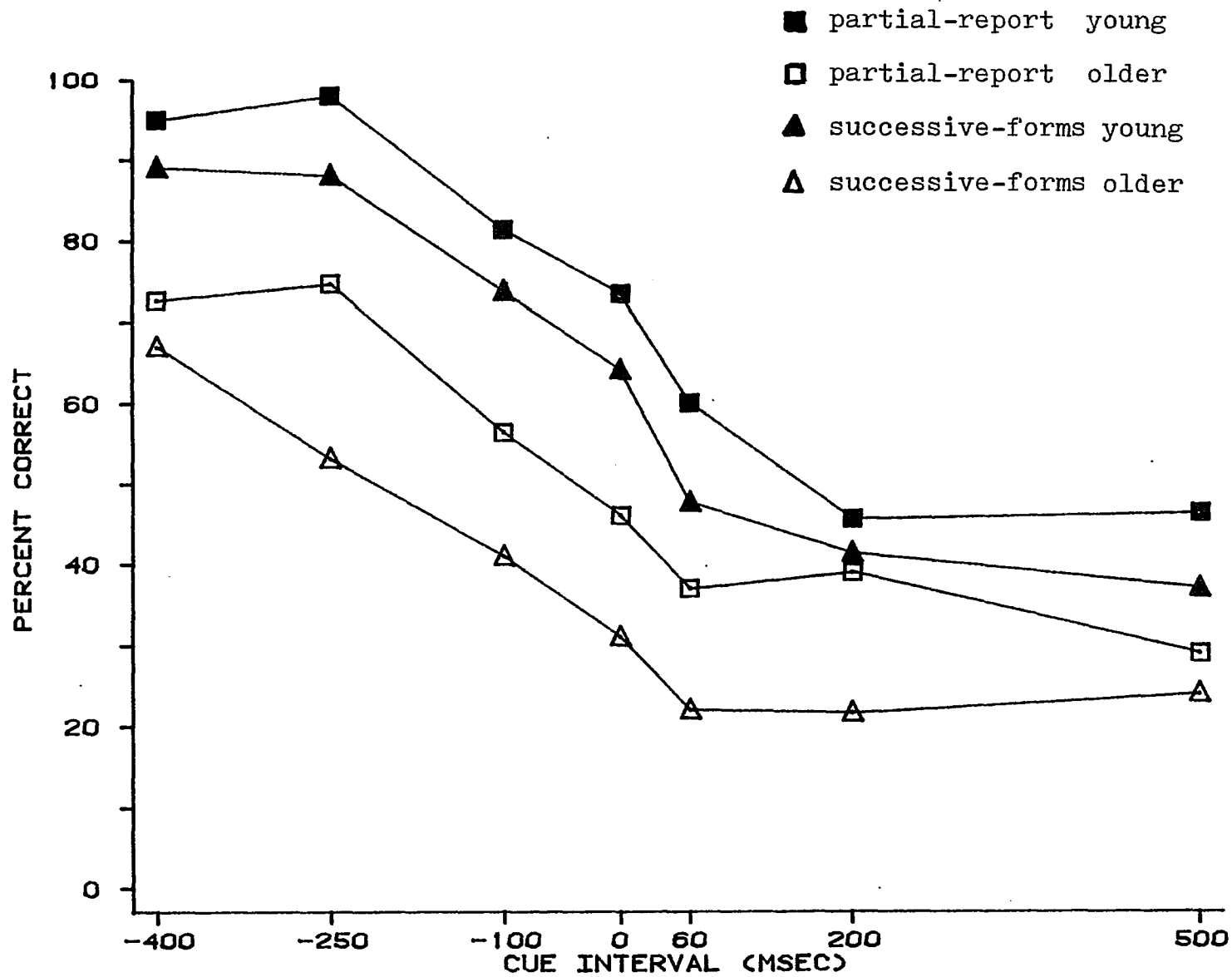
significantly fewer trials ($\underline{M} = 2.17$; $\underline{SD} = 0.98$) than the older group ($\underline{M} = 4.33$; $\underline{SD} = 2.06$), $\underline{t}(10) = 2.32$, $\underline{p} < .05$. In the successive-forms procedure one young adult and three older subjects took more than 20 trials to reach the criterion. However, for this procedure the young adult group ($\underline{M} = 7.83$; $\underline{SD} = 8.54$) and the older group ($\underline{M} = 16.50$; $\underline{SD} = 8.17$) did not differ, $\underline{t}(10) = 1.80$, n.s.

The young adult group also participated in an additional control procedure which was designed to measure the level of performance that could be achieved using only the information contained in the second half-letter displays of the successive-forms procedure. In this control procedure the second half-letter displays were presented for 35 trials (the first 10 of which were considered as practice) at both the -400 msec and the 500 msec cue intervals. The subjects were advised that they would have to guess the correct identity of the letters. These trials were given upon completion of the successive-forms procedure.

Results

Figure 7 shows the mean percentage correct performance for the young adult and older groups in the two procedures. As was found in Experiment 1 the successive-forms procedure was more difficult than the partial-report procedure. This was true at all cue intervals and for both groups. In both procedures the older group found the task more difficult than the young adult group at all cue intervals.

Figure 7: Percentage correct as a function of cue interval for the young adult (N = 6 subjects) and older (N = 6 subjects) groups in the partial-report and successive-forms procedures.



Since the main interest was to compare the duration of the process present in each procedure for the young adult and older groups, the results for the two procedures were analysed separately in two 2x7 (age group x cue interval) split-plot analyses of variance, where the cue interval factor was repeated. A .05 level of significance was used for all comparisons which resulted in an experimentwise Type I error rate of approximately 0.30.

Partial-report procedure

Inspection of the partial-report curve for the young adult group in Figure 7 shows that performance decreased as the cue interval was increased except from the -400 msec cue interval (95.00%) to the -250 msec cue interval (98.00%) and from the 200 msec cue interval (45.67%) to the 500 msec cue interval (46.33%). Inspection of the partial-report curve for the older group in Figure 7 shows that performance decreased as the cue interval was increased for all cue intervals. Performance at the 500 msec cue interval (46.33% for the young adult group and 37.00% for the older group) was below the expected baseline of 53.75%, calculated from the whole-report data of Sperling (1960).

The analysis of variance for the data of the partial-report procedure (see Appendix 7) showed no significant main effect of age group, $F(1, 10) = 1.97$, n.s., and no significant age group x cue interval interaction, $F(6, 60) < 1$, n.s., but the overall main

effect of cue interval was significant, $F(6,60) = 62.13$, $p < .001$. As there was no significant interaction the Shaffer-Welch test was used to analyse this significant overall main effect of cue interval to determine the longest cue interval at which performance was significantly higher than baseline (500 msec) performance. Performance at the 60 msec cue interval (53.83%) was significantly higher than baseline (500 msec) performance (41.67%), Shaffer-Welch $.05(60)$ critical value = 9.74. This result was the same as that found in Experiment 1A and gives the same duration of iconic memory, 310 msec (ie. 60 msec + cue processing time) to 750 msec (ie. 500 msec + cue processing time). In Experiment 1B this duration was 450 msec (ie 200 msec + cue processing time) to 750 msec.

Successive-forms procedure.

Inspection of the successive-forms curve for the young adult group in Figure 7 shows that performance decreased as cue interval was increased except from the -400 msec cue interval (72.67%) to the -250 msec cue interval (74.67%) and from the 60 msec cue interval (37.00%) to the 200 msec cue interval (39.00%). Inspection of the successive-forms curve for the older group in Figure 7 shows that performance decreased as the cue interval was increased except from the 200 msec cue interval (21.67%) to the 500 msec cue interval (24.00%).

The analysis of variance for the data of the successive-forms procedure (see Appendix 8) showed the

overall main effect of age group to be significant, $F(1, 10) = 8.69$, $p < .05$, indicating that the older group performed significantly lower than the young adult group. The overall main effect of cue interval was significant, $F(6, 60) = 51.79$, $p < .001$. There was no significant age group x cue interval interaction, $F(6, 60) = 1.61$, n.s., so the Shaffer-Welsh test was used to analyse the significant overall main effect of cue interval to determine the longest cue interval at which performance was significantly higher than baseline (500 msec) performance. Performance at the 0 msec cue interval (38.50%) was significantly higher than baseline (500 msec) performance (26.50%), Shaffer-Welsh $.05(60)$ critical value = 8.64. This result was the same as that found in Experiments 1A and 1B and gives the same duration of phenomenal persistence, 250 msec (ie. 0 msec + cue processing time) to 310 msec (ie. 60 msec + cue processing time).

In the control condition the young adult group was shown the second half-letter display only at the -400 msec and the 500 msec cue intervals. At the -400 msec cue interval mean performance was 33.67%, which was approximately half (46%) the mean performance for the young adult group in the successive-forms procedure at this cue interval (72.67%). At the 500 msec cue interval the control condition score was 16.67% which was again approximately half (58%) the mean performance for the young adult group in the successive-forms procedure at this cue

interval (29.00%). Thus, approximately half the information needed to identify the letters was contained in the first half-letter displays.

Top row versus bottom row performance

As in Experiment 1 all subjects performed better with the top row ($\underline{M} = 65.31\%$, $\underline{SD} = 10.14$) than the bottom row ($\underline{M} = 45.90\%$, $\underline{SD} = 11.40$) averaged over both procedures. This difference was significant, $t(11) = 8.56$, $p < .001$. For the partial-report procedure the ratio of percentage correct on the top row to percentage correct on the bottom row was 1.25 for the young adult group and 1.42 for the older group. For the successive-forms procedure this ratio was 1.36 for the young adult group and 1.97 for the older group.

Discussion

Eriksen and Steffy (1964), Abel (1972), Walsh (1975) and Salthouse (1976) had noted an inability of older subjects to perform the partial-report task with brief stimulus durations. However, in this experiment, the age group \times cue interval interaction was not significant and the older group produced a partial-report function of similar shape to the young adult group. The older group required significantly more practice trials to reach the criterion and performed more poorly at all cue intervals than the young adult group.

Partial-report performance by the young adult group at the -400 msec cue interval was lower than that at the -250

msec cue interval showing that these subjects did not benefit from the extra time given to process the cue. Partial-report performance by the older group at the -400 msec cue interval (89.00%) was only slightly higher than performance at the -250 msec cue interval (88.00%). Three of the older subjects and one of the young adult subjects had higher scores at the -400 msec cue interval than at the -250 msec cue interval.

The fact that more older subjects than young adult subjects showed a superiority of the -400 msec over the -250 msec cue interval was probably a reflection of the young adult group being closer to ceiling performance at the -250 msec cue interval (98.00%) than the older group (88.00%). The older subjects did not benefit significantly from the extra 150 msec given to process the cue. Optimal cue processing time was closest to 250 msec for both groups. Therefore, the hypothesis of Walsh and Prasse (1980), that older subjects do poorly on the partial-report procedure because of their inability to process the cue within the time limits available, was not supported. A question remains as to why the older subjects were able to perform in this study with the partial-report procedure using a short stimulus duration, and yet not in previous studies.

Several possible reasons for the relative success of the older subjects in this study as compared to prior investigations were the use of: (1) relatively large

stimulus letters; (2) subjects who did particularly well on the Ravens Coloured Progressive Matrices (90th percentile); and (3) negative cue intervals. The first two reasons can be discounted when the performance of the older subjects on the successive-forms procedure is considered because, as will be shown, the same subjects did relatively poorly with the same sized stimuli when compared with the results of previous studies. The crucial factor which enabled the older subjects to perform the partial-report procedure with a short stimulus duration appears to be the use of negative cue intervals.

In Eriksen and Steffy (1964) and Walsh (1975) the older subjects were trained at cue intervals of 10 msec and 0 msec respectively and these were the smallest cue intervals used. Employing negative cue intervals not only established a much higher initial value from which decreases in performance with increasing cue interval size (the hallmark of iconic memory) could be measured, but also gave the older subjects confidence that they could perform adequately on the task.

The older subjects did perform at a lower level than the young adult subjects on the partial-report procedure. Since this occurred at all cue intervals, including initial registration at the -400 msec and -250 msec cue intervals, it is most likely attributable to a reduction in letter identification ability as a result of a variety of retinal changes which occur with advancing age. Fozard, Wolf,

Bell, McFarland and Podolsky (1977) have outlined such changes which include clouding of the vitreous humour, yellowing of the lens, decreases in pupil size (senile miosis) and a reduction in the size of the visual fields. These changes serve to reduce the amount of light entering the eye and thereby the spatial resolving power or acuity of the retina.

Salthouse (1976) found significantly poorer partial-report performance in an older group and attributed this in large part to the adoption of a suboptimal performance strategy by the older group. However, this inferior performance strategy was not apparent until subjects had reported at least three letters. Salthouse found no difference in performance strategy between older and young adult subjects in reporting two letters. Cerella, Poon and Fozard (1982) also noted that older subjects are inferior to young adult subjects at reporting more than two letters at a time. Since only two letters had to be reported on each trial in this study it is unlikely that the older subjects had an inferior performance strategy to the young adult subjects although they did have a higher top:bottom performance ratio.

DiLollo et al. (1982) suggested that with advancing age performance on tasks involving central processing is reduced because of a general slowing in the rate at which information is processed. The performance of the older subjects in the partial-report procedure in this experiment

suggests that such a hypothesis is too general. Older subjects were shown to have similar performance to young adult subjects on an iconic memory task once the age related retinal changes which decrease letter identification performance were considered.

A comparison of the performance of the young adult and older groups on the successive-forms procedure shows a similar relationship to that found with the partial-report procedure. The age group x cue interval interaction was not significant but the older group performed more poorly than the young adult group at all cue intervals. Previous studies have found older subjects to have greater phenomenal persistence than young adult subjects in terms of both higher percentage correct (Kline & Orme-Rogers, 1978) and longer duration (DiLollo et al., 1982). The results obtained here showed the older group to score significantly lower in percentage correct and to have the same duration of phenomenal persistence as the young adult group (as baseline was reached by both groups at the 60 msec cue interval).

The most likely reason for the difference between the results obtained in this study and those of Kline and Orme-Rogers (1978) and DiLollo et al. (1982) is the difference in difficulty of the letter identification task required of the subjects. In Kline and Orme-Rogers (1978) subjects were required to identify which of 12 three letter words was presented (in successive-halves) on each trial:

(CAP, CAT, COP, COT, SAP, SAT, SIP, SIS, HIP, HIS, HOT, and HOP). The probability of getting the word correct was 1 in 12 by chance alone, 1 in 4 if the first or second letter was identified, 1 in 2, 4, or 6 depending on which last letter was identified, and 1 in 2 if the first two or last two letters were identified. Both the young adult and the older groups scored at 100% correct with an interpulse interval of 0 msec.

In DiLollo et al. (1982) subjects were presented simultaneously with two 5x5 dot matrices to the left and right of fixation. The dots in each matrix were plotted successively and the subject was required to report the matrix which contained a missing dot. The probability of being correct by chance alone was 1 in 2.

The task of the subjects in the successive-forms procedure used here was much more difficult. Two letters had to be identified on every trial, each with a probability of 1 in 14. In addition, these two letters had to be selected from among eight possibilities by processing the visual cue.

The successful performance of the older subjects on the partial-report procedure suggests that the older subjects could process the cue. It appears that some aspect of letter identification in the successive-forms procedure was particularly difficult for the older subjects.

The stimuli used in the successive-forms procedure

were more difficult to identify than the stimuli used in the partial-report procedure. This was found to be true for both the young adult group and the older group. It is probable that the retinal changes which occur with advancing age made it more difficult for the older group to distinguish between successive-forms letters which differed only slightly from each other (e.g., B and D, C and G, F and P). In Kline and Orme-Rogers (1978) subjects were required to distinguish between C, H, and S; A, O, and I; and P, S, and T -- letters which are physically dissimilar from each other.

The performance of the young adult group in the partial-report procedure and the successive-forms procedure was similar to that seen in Experiment 1, where only young adult subjects were tested.

For the young adult group in the partial-report procedure relative performance between the 200 msec and the 500 msec cue intervals varied between this experiment and Experiments 1A and 1B. In Experiment 1A, 200 msec performance was higher than 500 msec performance, but not significantly so; in Experiment 1B this difference was significant; and in this experiment 200 msec performance (45.67%) was slightly below 500 msec performance (46.33%). Estimating the duration of iconic memory as being from 310 msec to 750 msec encompasses all three outcomes.

In the successive-forms procedure the young adult group reached baseline at the 60 msec cue interval. This

also occurred in Experiments 1A and 1B, giving a duration of phenomenal persistence of 250 msec to 310 msec.

In conclusion, this experiment verified the finding of Experiment 1 that iconic memory is of longer duration than phenomenal persistence, for older as well as young adult subjects. The hypothesis of Walsh and Prasse (1980) that older subjects have difficulty with the partial-report procedure because of an inability to process the cue within the time limits of the procedure was not confirmed. Except that their overall performance level was lower, older subjects showed similar partial-report performance to young adult subjects at all cue intervals. The lower performance level may reflect retinal changes with advancing age which reduce resolving power and consequently letter identification ability. The hypothesis that phenomenal persistence increases with advancing age, as was shown by Kline and Orme-Rogers (1978) and DiLollo et al. (1982), was also not supported, probably because of the more difficult nature of the letter identification task, where age-related retinal changes probably outweighed any advantage due to greater phenomenal persistence in the older subjects.

Summary: Experiments 1 and 2

Differences between iconic memory and phenomenal persistence were obtained in response to stimulus energy manipulations and in measurements comparing older and young adult subjects. Iconic memory, defined as visual information in a stimulus continuing to be accessible after stimulus offset, was measured with a Sperling partial-report procedure. Eight randomly selected letters were presented tachistoscopically in four columns of two and a visual cue, presented at six different intervals from 250 msec before, to 500 msec after, letter offset, designated one of the columns for the subject to report. Phenomenal persistence, defined as a visual stimulus continuing to be visible after its physical offset, was measured with a modified Eriksen and Collins successive-forms procedure. This procedure was identical to the partial-report procedure except that the letter display was presented as two complementary half-displays which, when superimposed spatially and temporally, formed the partial-report eight letter display.

In Experiment 1A, the results from six young adult subjects showed iconic memory to be of longer duration (310-750 msec) than phenomenal persistence (250-310 msec) and to be unaffected by increases in stimulus duration (from 17 msec to 50 msec) or stimulus intensity (from 0.15 ftL to 1.5 ftL). Phenomenal persistence was inversely related (lower percentage correct) to increases in stimulus

duration and stimulus intensity.

In Experiment 1A the interpulse interval between the two half-letter displays in the successive-forms procedure varied with the cue interval. In Experiment 1B two successive-forms procedures with constant interpulse intervals of 0 msec and 50 msec and a partial-report procedure were used. Stimulus duration was 17 msec and stimulus intensity was 1.5 ftL. The results from six young adult subjects showed iconic memory to again be of longer duration (450-750 msec) than phenomenal persistence (250-310 msec). In the successive-forms (50 msec) procedure, phenomenal persistence was reduced in both duration and in percentage correct from the successive-forms (0 msec) procedure. This was consistent with the results from previous studies which had used the successive-forms procedure.

In Experiment 2, iconic memory and phenomenal persistence measurements from six young adult ($\bar{M} = 23$ years) and six older ($\bar{M} = 61.7$ years) subjects were compared. The stimulus duration was 17 msec and the stimulus intensity was 1.5 ftL. The older group produced functions of similar shape to the young adult group but had a lower percentage correct. These results were at variance with previous research where older subjects had been found to have difficulty with the partial-report procedure, yet perform better than the young adults on phenomenal persistence measures. The relatively successful

performance of the older group on the partial-report procedure used here was attributed to the use of negative cue intervals which gave a higher baseline from which decrements in performance with longer cue intervals (the hallmark of iconic memory) could be measured. The poor performance of the older group on the successive-forms procedure relative to previous studies was attributed to the use of a more difficult letter identification task in this study, where age-related retinal changes which reduce visual acuity may have penalised the older group.

Overall, the results provided support for Coltheart's (1980a,b) contention that iconic memory, as measured by the partial-report procedure, and phenomenal persistence, as measured by the successive-forms procedure, are distinct processes. This finding was contrary to the traditional view (e.g., Long, 1980) which held that the partial-report procedure and the successive-forms procedure were measuring the same process.

Given that iconic memory and phenomenal persistence are distinct processes, one can speculate on the function of each to visual information processing. Coltheart (1980a) has reviewed evidence which suggests that the information in iconic memory which decays is not the identity but rather the exact location of the letters. Since phenomenal persistence is of shorter duration than iconic memory and is inversely related to stimulus energy changes its function may be to facilitate identification of

the letters. Phenomenal persistence does not, however, necessarily precede or coexist with iconic memory as with relatively long stimulus durations (200 msec) phenomenal persistence has not been measured. Iconic memory has been measured at this duration (DiLollo, 1977a). If iconic memory and phenomenal persistence do serve different functions then it is probable that the physiological mechanisms underlying each are entirely different.

Appendix 1

Instructions

The following instructions were read to each subject:

"Your task is to identify letters which will be flashed on the screen of the microcomputer. Only letters chosen from B, C, D, F, G, H, J, L, P, Q, R, S, T, and Y will appear. These letters are listed on the wall above the computer and you can refer to this listing at any time if you need to refresh your memory.

Each trial will begin with a fixation dot in the middle of the screen. You should fix your gaze on this dot and whenever you are ready press the spacebar. Eight letters will flash briefly on the screen. These letters will be chosen randomly by the computer and will always appear in four columns of two letters each. The computer will also randomly choose one of the four columns to present a cue. The cue consists of two bars of light which appear just above and just below the two letters in the particular column chosen. You must identify the two letters in the column in which the cue appears - always give the top letter first. You can take as much time to respond as you wish.

On some trials the cue will appear before the letters flash and on other trials the cue will appear after the letters flash, but you will be told in advance when the cue will appear. Some of the conditions will be hard and some you will find easy, but you should just try and do your

best on each trial. There are no catch trials.

At the end of every five trials the percentage of letters which you have correctly identified in their correct location will appear on the screen. The results will show the percentage you have correctly identified on the top and bottom lines separately, as well as the total.

When the letters are flashed do not try to read the letters from left to right. You should try and keep the percentage correct for the top and bottom rows as equal as possible. This is best done by keeping your gaze fixed in the middle of the screen where the fixation dot appears. We will have some practice trials to begin. Do you have any questions?"

Subjects were then shown a picture of the actual position of the eight letters on the screen and a sample cue.

Appendix 2

Experiment 1A: Analysis of variance summary table for the partial-report procedure (3x6 repeated measures).

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>
Subjects (S)	931.63	5		
Duration/intensity (A)	125.41	2	62.70	1.52
A x S	413.48	10	41.35	
Cue interval (B)	6875.18	5	1375.04	44.58**
B x S	771.05	25	30.84	
A x B	307.59	10	30.76	3.47*
<u>A x B x S</u>	<u>442.84</u>	<u>50</u>	8.86	
Total	9867.18	107		

** p < .001

* p < .01

Appendix 3

Experiment 1A: Simple main effects of the duration/intensity factor in the duration/intensity x cue interval interaction for the partial-report procedure. (dur = duration; int = intensity; S = subjects)

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>
Dur/int at -250 msec	2.33	2	1.17	<1
Dur/int x S at -250 msec	23.67	10	2.37	
Dur/int at -100 msec	26.78	2	13.39	1.61
Dur/int x S at -100 msec	83.22	10	8.32	
Dur/int at 0 msec	111.00	2	55.50	3.97
Dur/int x S at 0 msec	139.67	10	13.97	
Dur/int at 60 msec	200.11	2	100.05	4.25
Dur/int x S at 60 msec	235.22	10	23.52	
Dur/int at 200 msec	44.33	2	22.16	1.76
Dur/int x S at 200 msec	125.67	10	12.57	
Dur/int at 500 msec	48.44	2	24.22	<1
<u>Dur/int x S at 500 msec</u>	<u>248.89</u>	<u>10</u>	24.89	
Total	1289.32	72		

Appendix 4

Experiment 1A: Analysis of variance summary table for the successive-forms procedure (3 x 6 repeated measures).

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>
Subjects (S)	792.97	5		
Duration/intensity (A)	1235.39	2	617.69	15.29**
A x S	403.99	10	40.40	
Cue interval (B)	9607.64	5	1921.53	83.47**
B x S	575.57	25	23.02	
A x B	1182.39	10	118.24	10.29**
<u>A x B x S</u>	<u>574.30</u>	<u>50</u>	11.49	
Total	14372.25	107		

** p < .001

Appendix 5

Experiment 1A: Simple main effects of the duration/intensity factor in the duration/intensity x cue interval interaction for the successive-forms procedure (dur = duration; int = intensity; S = subjects).

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>
Dur/int at -250 msec	1204.78	2	602.39	41.49**
Dur/int x S at -250 msec	145.22	10	14.52	
Dur/int at -100 msec	382.33	2	191.16	6.08*
Dur/int x S at -100 msec	314.34	10	31.43	
Dur/int at 0 msec	794.11	2	397.05	19.03**
Dur/int x S at 0 msec	208.56	10	20.86	
Dur/int at 60 msec	5.44	2	2.72	<1
Dur/int x S at 60 msec	105.23	10	10.52	
Dur/int at 200 msec	14.33	2	7.17	<1
Dur/int x S at 200 msec	84.34	10	8.43	
Dur/int at 500 msec	16.77	2	8.38	<1
Dur/int x S at 500 msec	121.23	10	12.12	
<u>Total</u>	<u>3396.68</u>	<u>72</u>		

** p < .001

* p < .025

Appendix 6

Experiment 1B: One-way analysis of variance summary tables for the partial-report procedure, the successive-forms (0 msec) procedure, and the successive-forms (50 msec) procedure.

Partial-report procedure

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>
Cue interval	11781.15	6	1963.52	35.90**
Subjects	704.77	5		
<u>Cue interval x subjects</u>	<u>1640.56</u>	<u>30</u>	54.68	
Total	14126.48	41		

Successive-forms (0 msec) procedure

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>
Cue interval	15233.14	6	2538.86	37.85**
Subjects	5506.77	5		
<u>Cue interval x subjects</u>	<u>2012.57</u>	<u>30</u>	67.08	
Total	22752.48	41		

Successive-forms (50 msec) procedure

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>
Cue interval	7454.66	6	1242.44	15.49**
Subjects	1450.76	5		
<u>Cue interval x subjects</u>	<u>2405.91</u>	<u>30</u>	80.20	
Total	11311.33	41		

** $p < .001$

Appendix 7

Experiment 2: Analysis of variance summary table for the partial-report procedure (2x7 split-plot factorial)

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>
Age group (A)	1491.86	1	1491.86	1.97
Subjects (S) within A	7563.52	10	756.35	
Cue interval (B)	33374.67	6	5562.44	62.13**
A x B	127.81	6	21.30	<1
<u>B x S within A</u>	<u>5371.81</u>	<u>60</u>	89.53	
Total	47929.67	83		

** p < .001

Appendix 8

Experiment 2: Analysis of variance summary table for the successive-forms procedure (2x7 split-plot factorial)

<u>Source of variation</u>	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>
Age group (A)	3949.72	1	3949.72	8.69*
Subjects (S) within A	4546.09	10	454.61	
Cue interval (B)	21851.14	6	3641.85	51.79**
A x B	681.62	6	113.60	1.61
<u>B x S within A</u>	<u>4219.24</u>	<u>60</u>	<u>70.32</u>	
Total	35247.81	83		

** p < .001

* p < .05

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