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Iconic Memory and Aging: Effects of Stimulus Duration, Stimulus Contrast, and Inter-Stimulus Interval

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ICONIC MEMORY AND AGING: EFFECTS OF STIMULUS DURATION, STIMULUS CONTRAST, AND INTER-STIMULUS INTERVAL

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-Scott

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ICONIC MEMORY AND AGING: EFFECTS OF STIMULUS DURATION, STIMULUS CONTRAST, AND INTER-STIMULUS INTERVAL

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Abstract

Previous studies have shown that old adults perform more poorly on the classic Sperling partial report task than do young adults. In this study, the researcher examined whether age differences in performance could be accounted for by changes in visual and perceptual ability. Eighteen old adults ($\underline{M}$ = 70 years) and 18 young adults ($\underline{M}$ = 22 years) were administered whole and partial report trials with stimulus durations of 150 ms; a second group of 18 young adults was tested with stimulus durations of 30 ms. Stimuli were presented at two levels of contrast (98 and 44 percent) and the partial report trials included four cue-delay conditions (0, 50, 150, 300 ms). Measures of processing speed, visual acuity, contrast sensitivity and word fluency were collected as predictor variables. Old adults demonstrated partial report superiority at the 0 ms cue-delay, but fell to whole report levels at longer delays. Young participants demonstrated partial report superiority across all cue-delays, regardless of stimulus duration. Letter recall was not influenced by stimulus contrast. Predictor variables, except word fluency, accounted for approximately equal amounts of age-related variability. Results suggest that factors such as processing speed and visual ability, rather than changes in iconic memory, may be responsible for age differences in partial report performance.

Introduction

Persons over the age of 65 represent the fastest growing sector of the American population. To meet the needs of our elderly citizens, it is becoming increasingly important that we understand the changes that occur with normal, healthy aging. Historically, age-related declines in ability have been documented for many cognitive tasks. However, recent research has suggested that differences between young and old participants may not be as clear cut as once believed. Extant studies of group and individual differences suggest that many of the declines in specific cognitive abilities can be explained by broader, underlying mechanisms such as processing speed.

Cognitive, developmental, and neuropsychologists are intensifying efforts to understand the complex web of mental processes. In the past ten years, findings have shown that changes in working memory, processing speed, and sensory abilities can account for much of the age-related variability in a host of cognitive tasks (e.g., Park et al., 1996; Salthouse, 1994; Baltes & Lindenberger, 1997). In this study, I will examine the relationships of processing speed and visual ability to iconic memory. Iconic memory is a very brief but high capacity memory storage which temporarily maintains a visual image after it is no longer physically present (Coltheart, 1980). Mixed results in the past have left an unclear picture as to whether there are age-related declines in the capacity and duration of iconic memory. Some have found age differences, but explained them as by-products of attentional deficits (i.e., Salthouse, 1976) or processing speed deficits (i.e., Walsh & Prasse, 1980). Others have found very minimal or no age differences (i.e., Gilmore, Allan & Royer, 1986). In this paper, I will outline some of the history of the study of iconic memory and aging and discuss the influence of sensory and processing demands on age differences in iconic memory.

Iconic Memory and Aging

Prior to 1960, researchers investigating a person's ability to process visually-presented information used a technique called the whole report. In a typical whole report task, participants view a matrix of letters for approximately 50 ms and then recall as many letters as possible. Using this technique, Miller (1956) found that participants could consistently recall about 6 or 7 letters, regardless of the total number of letters in the matrix. Most participants, however, insisted they had seen more of the display than they could remember. By the time they finished saying the first few letters, their memory of the remaining letters had faded away. Miller believed this inability of the participants to recall as many letters as they had seen implied a memory limit, which he called the Span of Apprehension.

To circumvent this memory limit, Sperling (1960) had participants report only a small, but randomly selected, portion of the matrix. In the Sperling task, called the partial report, participants recall only the letters in the row indicated by a cue. The cue, however, is not presented until after the matrix has been removed. Thus, to correctly recall the cued row, the participant must maintain the entire matrix in memory until the cue is presented. The number of correct responses is then multiplied by the number of rows in the matrix to provide an estimate of the total number of letters temporarily accessible to the subject.

On average, Sperling found that participants could report three, and sometimes all four, of the letters in the cued row. When this value was multiplied by the number of possible rows, it indicated to Sperling that the participants had actually processed about 76 percent of the matrix. Under whole report conditions, he found that participants could recall only about 40 percent of the matrix. The difference between the conditions reflected a partial report superiority.

Sperling varied the time interval between the offset of the stimulus and the onset of the cue. This delay in cue onset was called the inter-stimulus interval (ISI). He found that as the ISI was increased, the number of letters available for reporting decreased. When the

ISI was 500 ms or longer, participants could recall only about as much information as they could when asked to report the whole matrix. These findings suggested that for a period of less than 500 ms, participants could actually access more information about the visual image they had seen than they could verbally report. Sperling suggested there must be a very brief, but high capacity, storage which holds information before it is transferred to short-term memory. Neisser (1967) labeled this transient memory store iconic memory. The icon, he said, is a preliminary storage mechanism for sensory information that allows the observer to access the visual image for a short while after the physical image has been removed.

Coltheart (1980) believed that Sperling's demonstration that participants could temporarily access more information than they could report indicated that the memory store Sperling was testing was qualitatively different from short-term memory. Iconic memory, he said, is characterized by a high capacity and short duration. Short-term memory, on the other hand, is more durable but has considerably smaller capacity, as evidenced by Miller's findings. Another distinction, Coltheart suggested, is that iconic memory is highly susceptible to disruption by backward masking, whereas short-term memory is not.

When a visual image is formed in iconic memory, it is held temporarily while important information is transferred to short-term memory. If no part of the image is deemed important, then random elements of the image are moved to the short-term store before the icon fades. Coltheart called this type of transfer nonselective transfer. However, if a part of the image is cued, it can be transferred first. This type of transfer is called selective transfer. In the whole report task, participants typically use a nonselective transfer strategy because no one part of the matrix is more important than another. In the partial report, however, because the cue causes one row to be considered important, participants typically use a selective transfer strategy. A study by Gegenfurtner and Sperling (1993) demonstrated that a person has some control over the type of transfer strategy he or she uses. They found that if the participants believed the ISI would be long, they would employ a nonselective transfer, whereas if the ISI was believed to be short, the participants would wait until the cue appeared before transferring elements (i.e., selective transfer).

Several parameters can influence partial report performance. The entire letter matrix should be small enough so that the participant can visualize it without having to make an additional eye movement (e.g., Gilmore, Allan, & Royer, 1986). Therefore, the stimulus should fall within about 4 or 5 degrees of visual angle to ensure parafoveal presentation. For partial report facilitation to occur, the ISI can not extend past about 500 ms. Otherwise, as Sperling (1960) demonstrated, the icon would fade and recall would fall to whole report levels. The icon is very susceptible to disruption by a backward visual mask (Coltheart, 1980); therefore, if a visual cue is to be used, it should be placed such that the cue does not overlap with any of the letters in the stimulus (Black & Barbee, 1985).

The persistence of the icon can be influenced by the contrast of the stimuli. Long and Beaton (1982) found increased letter recall when the target luminance was high and the background fields were dim. However, as the luminance of the background fields was increased, letter recall worsened. The effects of lowered target-to-background contrast was especially detrimental to letter recall at long ISIs. These findings led Long and Beaton to suggest that partial report performance reflects an "energy-sensitive persistence" which is susceptible to changes in both target and background luminance. Furthermore, Long and O'Saben (1989) found that independent manipulations of background and target luminance in a successive-field task produced mixed results. For instance, a target luminance that improved letter recall at one background level hindered performance at a different background level. Their conclusion was that various stimulus conditions can influence the pattern of results and inferences drawn. In fact, they believed "Any factor that alters target clarity will affect persistence estimates" (p. 207).

Early efforts to measure the effects of age on iconic memory led to the suggestion that older adults could not demonstrate a partial report superiority, particularly at long ISIs. For instance, Salthouse (1976) found that, while the letter recall of young and old participants in the whole report trials was similar, younger participants could demonstrate a partial report superiority, but older adults could not. Older adults, he suggested, did not benefit from the cue in recalling letters in the matrix. However, rather than concluding that there were age differences in iconic memory, Salthouse suggested that performance differences were due to differences in the attentional strategies employed by the participants. Younger subjects were better able than the older subjects to attend to all areas of the array. Furthermore, Salthouse suggested, differences in processing speed might also account for age differences in performance.

Walsh and Prasse (1980) examined age differences in iconic memory. They found that nearly 80 percent of older participants could not perform under partial report conditions when displays were presented for 50 ms. However, when the stimulus duration was increased to 500 ms, many older adults could demonstrate a partial report superiority. These findings lent credence to Salthouse's (1976) suggestion that age differences in partial report performance were due to differences in processing speed. Walsh and Prasse (1980) stated that the time needed to process both the stimulus and the cue was greater for older adults than younger adults. And, as a result, the older adults had less time to access information from the icon.

Coyne, Burger, Berry, and Botwinick (1987) reached a similar conclusion. In their study, older participants were able to demonstrate a small, but reliable, partial report superiority when presented with a 2 x 4 letter array for 50 ms. An auditory cue, which immediately followed stimulus offset, indicated which of the two rows participants should report. However, while older participants did show an advantage, the partial report advantage demonstrated by the young participants was much greater. Differences in processing speed, as measured by choice reaction time, were shown to account for much of the age-related differences in partial report performance. The authors concluded that the age-related slowdown in visual processing speed, rather than changes in the duration of the icon, prohibited the older participants from showing as much partial report facilitation as the younger participants.

Gilmore, Allan and Royer (1986) conducted a study to determine whether the partial report procedure should be used to measure iconic memory in older adults. They paid special attention to experimental conditions that may have favored the younger subjects and put older subjects at a disadvantage. For instance, they used a 3 x 3 letter stimulus array which subtended a visual angle of 2.8° x 1.7° to insure that the older subjects could fully see the letter display. In addition, to equalize processing speed differences, Gilmore et al. used stimulus durations of 200 ms for the older subjects and 30 ms for the younger subjects. The results indicated that iconic memory could be validly assessed in both age samples, provided that special care was taken with the older participants. Gilmore et al. found no difference between the two age groups in partial report superiority at 0 ms ISI. They also measured performance with ISIs of 50, 100 and 150 ms. While partial report facilitation did decrease with increasing ISI, superiority over the whole report was maintained by older and younger subjects across all ISIs.

Results from these studies (e.g., Coyne et al., 1987) indicate that the ability to access and use information stored in iconic memory declines with advancing age. They suggest that age-related changes in the speed of visual processing contribute to age differences in partial report performance. In a review of the literature, however, Kausler (1994) commented on the ambiguity of results concerning age-related declines in capacity or duration of iconic memory. He suggested that none of the studies to date conclusively state whether there is a marked decline in the icon's capacity or duration associated with old age.

Age Differences in Cognitive and Sensory Abilities

Dozens of studies have demonstrated that young adults perform better on most cognitive tasks than older adults. Until recently, investigators have been reporting isolated changes in ability, such as age-related declines in selective attention. Salthouse (1994), however, suggested that age differences in performance might not reflect deficits in specific cognitive abilities, but rather reflect age-related changes in broader, underlying mechanisms. Processing speed, he said, should be considered one of the prime factors which mitigate performance on cognitive tasks. In one study by Salthouse (1994), he found that processing speed, which generally slows with old age, could account for most of the age-related variability on tasks of spatial rotation, matrix reasoning and associative memory.

Lindenberger, Mayr and Kliegel (1993) examined the influence of processing speed on measures of fluid intelligence and memory in a large, age-stratified sample of old and very old adults. They found that speed accounted for a large portion of the age-related variance in performance on tasks of reasoning, memory, knowledge, and fluency. When speed was statistically equated, many of the age differences in fluid intelligence disappeared. The authors of the study concluded that speed should become an integral component of theoretical accounts of cognitive aging.

In a large individual differences study of memory performance, Park et al. (1996) suggested that the influence of speed depended on the type of memory being measured. They found, for instance, that measures of processing speed were useful in predicting age decrements in performance on tasks such as cued recall and spatial memory. However, when the task was more resource-intensive, such as free recall, measures of working memory were better predictors of age-related declines than speed. Old age, these studies seem to suggest, is commonly associated with deficits in the ability to process information quickly. Subsequently, when a specific cognitive ability is being measured, the age-related differences that arise might reflect changes in processing speed rather than changes in higher-level cognitive processes such as reasoning or memory. Processing speed, however, should not be considered the only cause of age-related cognitive differences.

Another explanation for age differences in cognitive ability involves changes in the sensory system. It has long been recognized that the capacity of the sensory system to process environmental information changes across the life span, even in the absence of disease (e.g., Weale, 1963; Sekuler & Blake, 1990). For instance, after reaching peak performance during the second decade, the visual system begins a slow decline that progressively worsens with age. Towards the later years of life, the amount and quality of visual information processed from the surrounding environment is reduced considerably.

These changes in the visual system are pervasive, affecting nearly every aspect of normal vision (e.g., Kline & Scialfa, 1996). For instance, by the mid-forties, changes in the flexibility of the lens prohibit the average person from accommodating sufficiently to bring very close objects into focus (Sekuler & Blake, 1990); this loss is virtually complete by age 60. Visual acuity has also been shown to decline with normal aging. While corrective measures, such as prescription glasses, alleviate some of the deficiencies in acuity, there is an apparent limit to the acuity an older person can achieve. Owsley, Sekuler and Siemsen (1983), for instance, found that old adults, who were wearing correctly-prescribed optics, performed more poorly than young adults on tasks that required the discrimination of fine spatial detail.

Visual pattern discrimination is also affected by age. Owsley et al. (1983) found that beginning at around age 40, the ability to discriminate small changes in pattern detail declines. After plotting the contrast sensitivity functions (CSF) of both old and young participants, it was shown that the peaks of the CSF for older and younger adults differed by about 2 cycles per degree. (A person's CSF reveals the extent to which his or her ability to discriminate fine details is influenced by contrast.) This finding indicated that young adults were more sensitive to higher spatial frequencies than older adults. In addition, Gilmore (1996a) reported that older adults required higher contrast than young adults to detect lower spatial frequencies. These studies suggest that older adults are less sensitive than younger adults to a broad range of spatial frequencies, especially under low stimulus contrast.

Furthermore, age affects the opening of the pupil causing a reduction in retinal illumination. This condition, called pupillary miosis, reflects the tendency of the older adult's pupil to remain at a small diameter despite low light levels. Weale (1963) reported a two-thirds reduction in retinal illumination for older adults when compared to young adults. Owsley et al. (1983) found that when retinal illumination was roughly equalized for 20-yr.-olds and 60-yr.-olds, the contrast sensitivity differences between the two age groups were minimized. In addition, Owsley and Burton (1991) reported that age differences in contrast sensitivity were more pronounced at lower luminance levels.

Studies of visually evoked potentials (VEPs) reveal that older adults require more time than young adults to cortically respond to a visual event. These age differences in the latency of cortical response, however, were found to be linked to the luminance of the display. When the luminance of the display was increased to high levels, age-dependent differences in cortical response were eliminated. Longer stimulus durations, which allow more stimulus energy to be absorbed by the eye, have also been shown to reduce age-related differences in measures of visual performance (for a review, see Gilmore, 1996a).

In summary, these studies indicate that, when compared with young adults, old adults require greater stimulus contrast, higher luminance and longer stimulus duration to process visually-presented information. Changes in the visual system can lead to behavioral manifestations which resemble changes in cognitive ability. Gilmore et al. (1996b) found, for instance, that the difficulties of Alzheimer's Disease (AD) patients in reading speed and comprehension could be overcome by simply increasing the contrast of the reading display. In fact, under very high contrast conditions, the performance of AD patients and healthy elderly adults was indistinguishable. Alternatively, healthy young and old adults were found to perform similarly to AD patients on object naming tasks when the stimulus contrast of the object was degraded (Gilmore, 1996a).

The Influence of Sensory Function and Processing Speed on Memory

It is intuitive that changes in the sensory system can influence the ability to cognitively process an environmental stimulus. A breakdown in the ability of the sensory system to accurately translate physical energy to neural energy can lead to inefficiencies in perceptual systems further down the line. If, for instance, changes in the structure of the eye cause a visual sensation to be seen as blurry or dark, then the perception of the sensation will not accurately reflect the true nature of the object. And, if an incomplete percept is formed, then any manipulation of it will be affected.

A recent study directly investigated this interaction of sensory and cognitive functioning. Salthouse, Hancock, Meinz and Hambrick (1996) took several measures of cognitive and sensory abilities in a large age-stratified sample. They found that differences in near-visual acuity accounted for large portions of the age-related variance on measures of working memory, associative learning and concept identification. Other variables, such as speed and working memory, were found to significantly contribute to the explanation of age differences. The authors proposed that speed, working memory, and sensory ability all reflect a common mechanism responsible for age differences. If factors such as visual acuity and speed could be statistically equated, they suggested, age differences in performance on a number of cognitive tasks would be minimized or eliminated.

Lindenberger and Baltes (1994) believed that age-associated changes in sensory and perceptual abilities reflect an overall decline at the neural level. Data they collected during the longitudinal Berlin Aging Study, which included a large sample of old to very old (70-100 years) participants, indicated that sensory measures acted as mediators of age-related variance and fully predicted intellectual differences. In an earlier report by Lindenberger, Mayr and Kliegel (1993), speed was found to be the primary mediator of the same types of tasks. However, Lindenberger and Baltes (1994) suggested that sensory abilities influence speed, whereas speed does not necessarily influence sensory abilities. Therefore, they proposed the following model of age-related changes in cognition: age affects vision and hearing, vision and hearing affect speed and speed affects intelligence.

A follow-up study (Baltes & Lindenberger, 1997) examined the relative contributions of sensory changes in both old age (70-103 years) and middle age (25-69 years). It was found that vision and hearing were more closely related to changes in intelligence in the old age group than in the middle age group. The authors proposed that there is a "common-cause" or general underlying factor which might be responsible for the age-related declines in cognitive and sensory functioning. In other words, age-related changes at the sensory and perceptual level reflect an overall decline in the efficiency of the brain to process incoming information.

Whether age-related changes in cognitive performance reflect deficits at the perceptual level, the sensory level or some interaction between the two has proven to be difficult to determine with correlational studies. One goal of the current study is to add to the understanding of the cognitive and sensory interaction by experimentally manipulating aspects of each in a measure of iconic memory.

The Present Study

The broad intent in this study was to determine if there is a significant difference between the duration of the iconic memory store in older and younger subjects and to examine whether aspects of an aging visual system affect iconic memory performance. To adequately measure the duration of the icon in both age samples, it was necessary to make adjustments to certain parameters of the whole and partial report procedure. One of these manipulations was stimulus duration. While the older participants in Gilmore et al.'s (1986) study demonstrated partial report superiority at a stimulus duration of 200 ms, I opted to use a stimulus duration of 150 ms for both young and old adults. It was believed that 150 ms would be sufficient time for the older adults to orient and focus on the letter matrix yet would prohibit potential eye movements by younger participants. A second set of young subjects was run at a stimulus duration of 30 ms to compare the effect of stimulus duration on performance.

A visual cue was used in this study to indicate which row the participant should report during the partial report trials. Previous studies using visual cueing, rather than auditory cueing, have indicated that a visual cue would cause interference in letter recall if placed within the space allotted to the letter matrix (i.e., Black & Barbee, 1985). Therefore, in this study, an effort was made to minimize visual masking from the cues. The cues were presented to the left of the letter matrix such that if the cue were present at the same time as the matrix the two would not overlap.

An attempt was made to measure the duration of the icon by manipulating the interval between the stimulus offset and cue onset. It was hypothesized that both age groups would perform progressively worse on longer intervals. Old adults, however, would be more adversely affected by the increased intervals. Based on previous findings, it was presumed that old age would cause the icon to fade or deteriorate more rapidly. Old adults would perform similarly to the young adults at short ISIs; at long ISIs, however, the young adults would outperform the old adults.

Additionally, the effect of stimulus contrast on letter recall was examined. It was hypothesized that if older adults do suffer from decreased contrast and luminance sensitivity, as has been reported previously, then their performance should suffer under conditions of low contrast. Young adults, on the other hand, should be able to adapt to changes in stimulus contrast.

The parameters of the stimuli were designed to allow older participants the opportunity to demonstrate partial report superiority. Stimuli were presented so that they were within the participant's fovea and parafoveal region (i.e., within 5 ° of visual angle). The duration of the stimuli was believed to be sufficiently within the limits of the slower processing speed of the older adult. In both contrast conditions, all participants could clearly see the individual letters of the stimuli, as evidenced by sample letter matrices read by the subject prior to testing.

Measures of individual differences, such as contrast sensitivity, visual acuity, and processing speed, were collected as a means of understanding the effects of age on iconic memory performance. It was believed that age-related changes in sensory ability and processing speed would be related to age differences in whole report and partial report performance. These individual difference measures, together with performance results from the experiment, were thought to provide a novel examination of iconic memory and aging.

In summary, it was predicted that partial report performance by all subjects would decline as the length of the ISI was increased. However, young adults would be able to maintain partial report superiority at longer ISIs while older adults would not. Secondly, it was predicted that the partial report performance of older adults would suffer under low contrast conditions. The relationship of sensory ability and partial report performance would be revealed in the changes of performances that accompanied changes in stimulus contrast. If, for instance, the older participants could demonstrate a partial report superiority under high contrast conditions but not low contrast conditions, then evidence would be provided for the influence of sensory processing on iconic memory.

Method

Participants

Thirty-six young (mean age was 21.67 years, ranging from 19 to 30 years) and 18 old (M = 69.78, ranging from 63 to 76 years) adults, recruited from Bowling Green, Kentucky, participated in the study. The young participants were randomly divided into groups of 18; the two groups did not differ significantly on any demographic attribute measured. A power analysis revealed that 18 participants per group, for a fixed alpha of .05 and a medium effect size, yielded a power of .68. Sample populations of approximately 20 are consistent with smaller cross-sectional studies of memory.

Young participants were recruited from Psychology classes at Western Kentucky University. Old participants were contacted and recruited from an existing subject pool. To be included in the study, participants were asked if they could read from a newspaper, could provide their own transportation to the testing room, and if they had at least a high school degree. A negative response to any of the questions resulted in the subject being excluded from the study. An attempt was made to match participants based on sex, although the iconic memory literature suggests that gender does not play a significant role in partial report performance (Coyne et al., 1987). The younger adults were given extra course credit, and older adults received a ten dollar check for participating. A demographic questionnaire was administered to obtain information about age, gender, health, education, and martial status. Summary statistics for the sample as a function of age group are shown in Table 1.

Table 1

Percentages of demographic data by group

		Young (30 ms)[A]	Young (150 ms)	Old (150 ms)
Gender				
	Male	50.0	44.4	38.9
	Female	50.0	55.6	61.1
Education				
	High School or G.E.D.	5.6	0.0	27.8
	2 or 4 yr. college	72.2	94.4	33.3
	Graduate school	22.2	5.6	38.9
Marital Status				
	Single	72.2	88.9	5.6
	Married	22.2	5.6	77.8
	Divorced	5.6	5.6	0.0
	Widowed	0.0	0.0	16.7
Overall Health				
	Excellent	38.9	33.3	27.8
	Good	55.6	61.1	61.1
	Fair	5.6	5.6	11.1
Comparative Health				
	Better	27.8	33.3	50.0
	Same	61.1	66.7	50.0
	Worse	11.1	0.0	0.0
Glasses				
	Yes	50.0	55.6	100.0
	No	50.0	44.4	0.0

Table 1 continued

Percentages of demographic data by group

		Young (30 ms)	Young (150 ms)	Old (150 ms)
Bifocals				
	Yes	5.6	0.0	100.0
	No	94.4	100.0	0.0
Mobility				
	Impaired	0.0	0.0	33.3
	Not impaired	100.0	100.0	66.7
Glaucoma				
	Yes	0.0	0.0	27.8
	No	100.0	100.0	72.2
Macular Degeneration				
	Yes	0.0	0.0	16.7
	No	100.0	100.0	83.3
Cataract				
	Yes	0.0	0.0	38.9
	No	100.0	100.0	61.1
Scotoma				
	Yes	0.0	0.0	5.6
	No	100.0	100.0	94.6

Note. [A] These labels indicate at which stimulus duration the participants were tested in the whole and partial report trials. Overall and comparative health are self-reported measures of perceived health relative to same age others. Mobility is a measure of night-time mobility. The variables, glasses and bifocals, reflect the type of visual aide worn by the participant. Eye disorders reflect self-reported indications of currently having or have had the particular condition.

Stimuli

A 3 x 3 letter matrix was used for the whole and partial report trials. Letters were randomly selected from the 20 consonants (the letter Y excluded) and were presented in 34 point, Courier font. In a letter matrix, no letter repeated and no three-letter combination was repeated throughout the trials. At a viewing distance of 30 inches (769.23 mm), each individual letter subtended a visual angle of .6°. The entire 9-letter matrix subtended a visual angle of 2.98° by 2.68°. The bar marker, which was 10 mm in length (.89°), was placed 7 mm to the left of the letter matrix. With the bar marker added, the visual angle increased to 4.47°. Letters in the high contrast condition appeared as white against an uniformly black background, causing a 98 percent contrast. Letters in the low contrast condition appeared as dull gray against the black background, causing a contrast of 44 percent. Contrast was defined as the difference between the maximum and minimum luminance, divided by their sum.

Setting and Apparatus

The study took place in a laboratory in the Department of Psychology at Western Kentucky University. During testing, the subject was seated facing the computer screen and the experimenter was seated behind and to the right of the subject. The testing room, which was approximately 9 ft. x 9 ft., was dimly lighted by a shielded 4 watt light bulb and the light emission from a laptop computer. Care was taken to insure neither the light nor the laptop computer caused a reflection or glare off the testing computer. The ambient light for the subject sitting in front of the computer under testing conditions was 10^{-1} cd/m^2, and lighting conditions were held constant for all subjects. Viewing conditions were approximately mesopic, or between photopic and scotopic (Sekuler & Blake, 1990).

Partial and whole report trials were presented on a Macintosh MultiScan 15" monitor. The monitor was full color and was run at a resolution of 640 x 480 pixels, at 67 Hz. Contrast and brightness settings on the monitor were held constant throughout data collection. The testing program was developed with SuperLab 1.68 for the Mac. Stimuli were developed with the Claris Works 2.0 program. The testing program was run on a stand-alone PowerPC™ Macintosh 7500/100 computer.

Design

In this study, I was interested in testing for both group and individual differences in memory for briefly-presented visual stimuli. Whole and partial report trials were presented in blocks of high and low contrast stimuli; four inter-stimulus intervals (ISI; 0, 50, 150, or 300 ms) were randomly presented during the partial report trials. Table 2 summarizes the order of presentation, which was counterbalanced to test for carry-over and practice effects. Performance of two groups of young adults (tested at 30 ms and 150 ms, respectively) and one group of old adults (tested at 150 ms) was compared in a series of repeated measures analyses, such that age was the between-groups factor and contrast and ISI were the within-subjects factors. Measures of visual acuity, contrast sensitivity, word fluency and processing speed were collected for use in correlation analyses.

Procedure

Participants were tested individually. Sessions lasted between 45 minutes and 1.5 hours, with most sessions about 1 hour in duration. When the participant arrived, he or she read and signed the informed consent (see Appendices A and B). It was stressed that participation was voluntary and that they could leave at any time.

The participant was seated in a stationary chair 30 inches from the front of the computer. The overhead lights were turned off. After a minute of staring at the darkened computer screen, the participant was shown instructions for the first test, called the F-A-S Word Fluency task. In this task, the participant pressed a key to begin and was shown the letter F on the screen for one minute. During the one minute period, the participant verbally

Table 2

Summary of contrast counterbalance and order of trials

Blocking	Order of Trials	Contrast	No. of trials/block
A	Whole Report	High	22
	Whole Report	Low	22
	Partial Report	High	96
	Partial Report	Low	96
B	Whole Report	Low	22
	Whole Report	High	22
	Partial Report	Low	96
	Partial Report	High	96

Note. Participants were randomly assigned to Blocking A or B, which determined the order of contrast they received. Eight practice trials were administered prior each block of trials.

named as many words beginning with the letter F as he or she could. Each word was counted by the experimenter and monitored to ensure that no word was counted twice. The procedure was then repeated for the letters A and S. This task lasted approximately 9 minutes. Though this measure is used commonly to assess the fluidity of semantic memory in old adults, its primary purpose in this study was to allow the participants time to adjust to the darkened room.

The second task of the study, the whole report, began with the participant reading a letter matrix from each of the contrast conditions. All participants were able to read all letters. The instructions for the whole report were then presented on the computer screen. The instructions informed the participants that there were only consonants in the letter matrices and that they should guess at letters they think they had seen. As summarized in Table 3, the participants were instructed to first fix their attention on a fixation cross, which was presented in the center of the screen for 800 ms. After an interval of 200 ms, they were flashed the nine letter matrix for 150 ms (or 30 ms, depending on group assignment). Once the matrix was no longer on the screen, the participant recalled as many letters as he or she could. The experimenter recorded responses by marking off correctly recalled letters on a scoring key. When ready to continue with the next trial, the participant pressed a key on the computer keyboard. Participants were given eight practice and 22 whole report trials of one stimulus contrast (high or low). After a short break, the instructions, practice and whole report trials were repeated in the second contrast condition.

On the partial report trials, participants were instructed to again fix their attention on the fixation cross and scan the nine letter matrix. However, participants were required to recall only the three letters in the row indicated by a bar marker. Guessing was encouraged. The bar marker was presented after the letter matrix was removed from the screen, and appeared after an interval of 0, 50, 150, or 300 ms (see Table 3).

Table 3

Order of events on whole report and partial report trials.

Event	Stimulus	Time (ms)	Subject task
Whole Report	Fixation Cross (+)	800	fixate gaze
	Pause (blank)	200	mentally prepare
	3 x 3 letter matrix	150 or 30	form iconic image
	Response (blank)	3000	recall letters
	Ready screen	self-paced	press any key
Partial Report	Fixation Cross (+)	800	fixate gaze
	Pause (blank)	200	mentally prepare
	3 x 3 letter matrix	150 or 30	form iconic image
	ISI (blank)	0, 50, 150 or 300	maintain icon
	Cue (10 mm line)	75	select, transfer row
	Response (blank)	3000	recall letters
	Ready screen	self-paced	press any key

Eight practice trials were given before beginning the actual trials. The actual trials consisted of 24 trials of each of the four ISIs for a total of 96 trials in each contrast condition. The position of bar marker was randomly chosen for the top row, middle row or bottom row, with the exception that the position of the bar marker was not repeated more than twice on successive trials. After a mandatory break of at least five minutes, the second set of partial report trials was administered. The participant was asked to remain in the darkened room for the entire period of whole and partial report trials. No participant left the room during testing.

The three letter responses were entered into a specially written scoring program on a laptop computer by the experimenter. The testing sessions were tape-recorded to double check the scoring at a later time. Participants completed a questionnaire (see Appendix D) and the older participants filled out a form for payment. They were then given a series of predictor measures. First, the participants completed the Vocabulary Test from the Shipley Institute of Living Scale (Shipley, 1986) as an indicator of verbal ability. The next individual differences measure collected was the Pattern Comparison Test (Salthouse & Babcock, 1991). This test measures processing speed by requiring participants to decide whether two patterns are the same or different. The test consists of three sections, with increasing difficulty, and the participant was instructed to make as many comparisons as possible within a 30 s time allotment. A maximum score of 96 was possible.

Two sensory measures were then taken. Visual acuity was measured at 4 m using the Bailey-Lovie Acuity Test. This chart produces a score that can be converted to a Snellen Equivalent. For instance, at 4 m, a score of 0.0 would be equivalent to 20/20. Negative values indicate better than 20/20 visual acuity. The mean luminance of the chart was approximately 100 cd/m^2. Participants wore normal optical aides during testing. Contrast sensitivity was measured at 1 m using the Pelli-Robson Contrast Sensitivity Chart. The Pelli-Robson chart consists of rows of letters that become progressively more faint. The point at which the observer could no longer read at least two of the 3 letters in a row was recorded. This point indicated the log contrast sensitivity. The higher the score, the greater the contrast sensitivity. Contrast for this type of chart is defined as the difference in luminance between the letter and the background, divided by the luminance of the background. The chart was lighted to approximately 100 cd/m^2. After the predictor measures were collected, the participant was debriefed and told that a copy of the final overall results would be made available to them upon request. Appendix C contains the verbatim instructions the experimenter used during the testing procedure.

Results

Findings from this study are reported in two sections. The first section is a discussion of the results of multivariate and univariate analyses. These analyses were used to break the data into smaller pieces that will show how the data evolved in a step-by-step fashion. The second section will include the correlations of four predictor variables (word fluency, visual acuity, contrast sensitivity, and processing speed). Significance for all statistical tests was evaluated at an alpha level of .05 unless noted otherwise.

Measure of Iconic Memory

The first step in calculating the partial report superiority (PRS) score was to multiply the average number of letters recalled in the partial report trials by three (the number of rows in the letter matrix). The average whole report score was then subtracted from this score to produce a measure of PRS. High contrast whole report scores were subtracted from high contrast partial report scores, and low contrast whole report scores were subtracted from low contrast partial report scores. The higher the PRS score, the more letters the participant was able to access from their icon.

Table 4 summarizes the correlations and reliability estimates of the whole report, partial report, and partial report superiority scores. To determine reliability, the trials from the high and low contrast conditions were considered parallel tests. As Table 4 shows, the Spearman-Brown estimates were quite high, indicating that the testing procedures were reliably similar to each other, despite changes in contrast. In addition, high reliability estimates were found for the partial report superiority scores except at 300 ISI.

As represented in Figure 1, the young participants had higher PRS scores than the old participants on all trials, regardless of stimulus duration, contrast or ISI. A 3 (group) x

Table 4

Correlations and reliability estimates of iconic memory performance.

Score (ISI)	Correlation	Estimate
WR	.821	.902
PR (0)	.897	.946
PR (50)	.833	.909
PR (150)	.791	.833
PR (300)	.684	.812
PRS (0)	.787	.880
PRS (50)	.731	.845
PRS (150)	.682	.811
PRS (300)	.383	.554

Note. Correlations are between the high and low contrast trials. Reliability estimates are calculated with the Spearman-Brown formula. N =54.

2 (contrast) x 4 (ISI) repeated measures Multivariate ANOVA was conducted to test for significant interactions. The 3-way interaction of group, contrast, and ISI was nonsignificant [Wilks's Lambda = .837, F (6,98) = 1.518, p= .180, eta^2 = .085]. However, significant two-way interactions were found for ISI and Age Group [Wilks's Lambda = .524, F (6,98) = 6.230, p< .01, eta^2 = .276] and for ISI and Contrast [Wilks's Lambda = .738, F (3,49) = 5.804, p< .01, eta^2 = .262]. The interaction of Contrast and Age Group was nonsignificant [Wilks's Lambda = .968, F (2,51) = .836, p = .439, eta^2 = .032]. The main effect of contrast on PRS scores was nonsignificant [F (1,52) = .004, p =.947, eta^2 < .001]. Paired-sample t-tests, conducted within groups, revealed that the only high-low contrast comparison to obtain significance was in the young (150 ms) group at the 150 ms ISI [t (17) = 3.88, p <.01]. All other high-low contrast comparisons of PRS scores were nonsignificant.

The main effect of ISI was significant [F (3,49) = 84.657, p <.01, eta^2 = .838]. Within the two young groups, paired-sample t-tests revealed that partial report superiority declined significantly with each ISI increment (i.e., 0 ms to 50 ms), under both contrast conditions. There were two exceptions. First, in the young (150 ms) group, under low contrast, there was no significant difference between the average PRS scores for the 150 ms ISI and 300 ms ISI [t (17) = -1.01, p =.326]. Second, in the young (30 ms) group, under low contrast, there was no significant difference between the average PRS scores for the 150 ms ISI and the 300 ms ISI [t (17) = .52, p =.610]. Within the young groups, one-sample t-tests revealed that PRS scores for each ISI were significantly greater than zero.

Within the old (150 ms) group, there was no significant difference between the PRS scores of each ISI increment, in either the high or low contrast conditions. Only the PRS scores at 0 ISI were significantly higher than zero (under high contrast, t (17) = 2.076, p < .05; under low contrast, t (17) = 2.328, p < .05). This finding suggests that the old participants were able to demonstrate a partial report superiority only when the ISI was at 0 ms, whereas young participants demonstrated partial report superiority at all of the ISIs

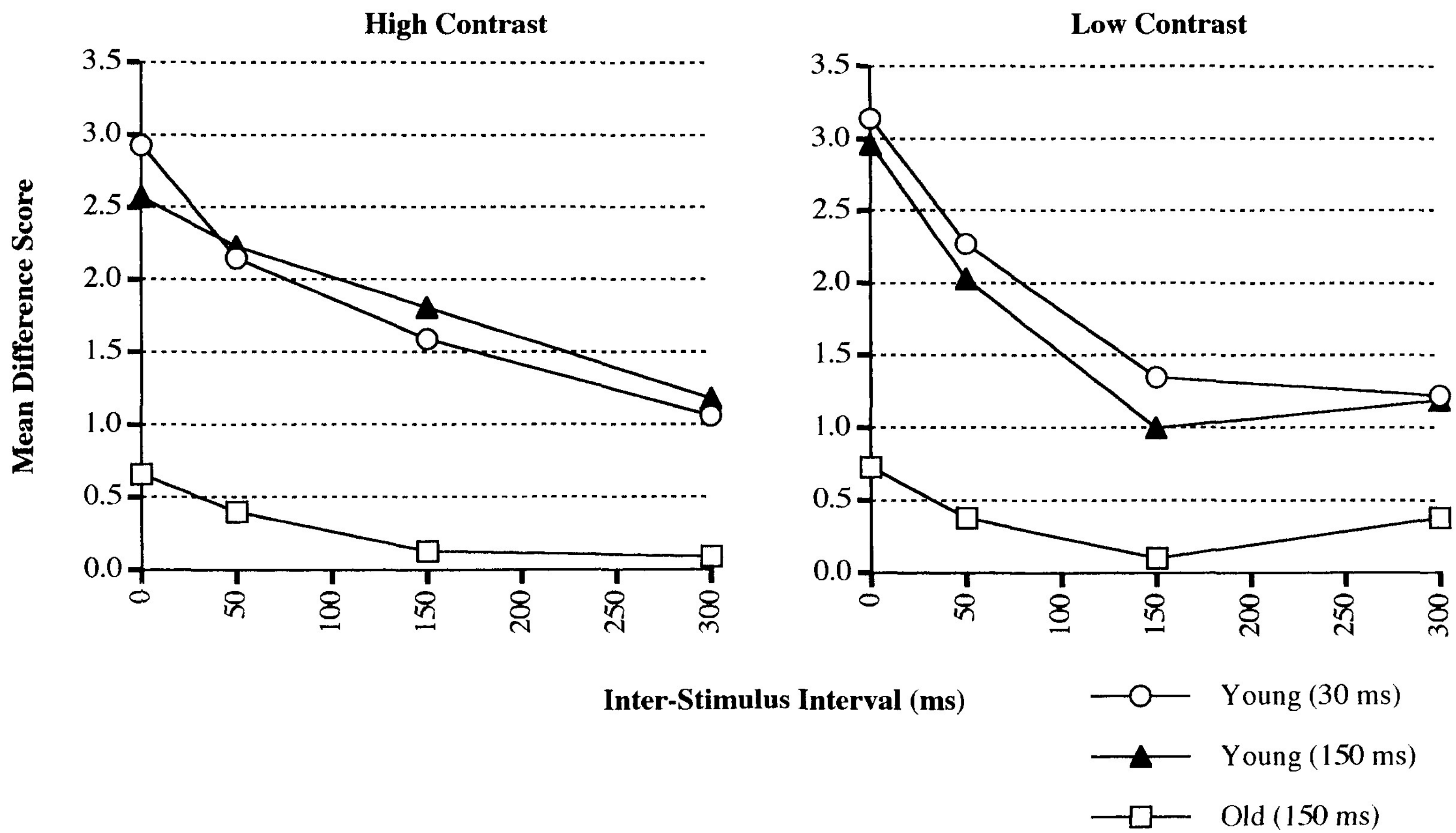

Figure 1. Partial Report Superiority, as a function of ISI and contrast.

under high and low contrast conditions. The main effect of Age Group on partial report superiority was significant [F (2,51) = 24.099, p <.01, eta^2 = .486]. Sheffe's analyses revealed that the two young groups differed significantly from the old group but did not differ from each other on any of the PRS scores.

Whole Report Performance

Table 5 summarizes the whole report (WR) scores under high and low contrast conditions for each age group. A repeated measures multivariate ANOVA was used to examine the effects of age group and contrast on the whole report performance. The results indicated that the two-way interaction of age group and contrast was nonsignificant [Wilks's Lambda = .940, F (2,51) = 1.624, p= .207]. The main effect of contrast was significant [Wilks's Lambda = .747, F (1,51) = 17.290, p< .01]. All age groups recalled more letters under high contrast conditions than low contrast conditions on the whole report trials. The main effect of age group was also significant [F (2,51) = 19.486, p <.01], with both young groups recalling more letters, on average, than the old group. Paired sample t-tests conducted for each age group revealed that both young groups recalled significantly more letters on the high contrast whole report trials than the low contrast trials. However, the old group did not differ significantly between the high and low contrast conditions in the number of letters they recalled [t (17) = 1.30, p = .211].

Partial Report Performance

Table 5 summarizes the means and standard deviations of the partial report (PR) scores under high and low contrast conditions for each group. These values represent the average number of letters recalled in the partial report trials. Most participants recalled fewer letters, on average, when the ISI was increased. In addition, letter recall tended to favor the high contrast conditions. A repeated measures ANOVA, which was set up as a 3 (age group) x 2 (contrast) x 4 (ISI), was conducted on the partial report data. The analysis

Table 5

Whole report and partial report performance by group, contrast, and ISI.

Trial Type	Contrast	ISI	Mean (Std. Dev.)		
			Young (30 ms)	Young (150 ms)	Old (150 ms)
Whole Report					
	High	N/A	4.59 (.98)	4.64 (.67)	3.35 (.51)
	Low	N/A	4.24 (.75)	4.21 (.48)	3.23 (.58)
Partial Report					
	High	0	2.51 (.26)	2.41 (.26)	1.34 (.51)
		50	2.25 (.40)	2.29 (.26)	1.25 (.47)
		150	2.06 (.49)	2.15 (.36)	1.16 (.45)
		300	1.88 (.43)	1.94 (.29)	1.15 (.29)
	Low	0	2.46 (.33)	2.39 (.36)	1.32 (.47)
		50	2.17 (.37)	2.08 (.32)	1.20 (.43)
		150	1.86 (.44)	1.74 (.39)	1.11 (.42)
		300	1.82 (.32)	1.80 (.31)	1.20 (.38)

revealed a nonsignificant omnibus F for the three-way interaction [Wilks's Lambda = .837, F (6,98) = 1.518, p = .180, eta^2 = .085]. The two-way interaction of contrast and age group was nonsignificant [Wilks's Lambda = .895, F (2,51) = 2.987, p = .059, eta^2 = .105]. The two-way interaction of ISI and age group was significant [Wilks's Lambda = .524, F (6,98) = 6.230, p <.01, eta^2 = .276]. The two-way interaction of contrast and ISI was significant [Wilks's Lambda = .738, F (3,49) = 5.804, p< .01, eta^2 = .262].

The main effect of contrast on partial report performance was significant [Wilks's Lambda = .818, F (1,51) = 11.349, p< .01, eta^2 = .182]. Participants tended to recall more letters on the high contrast trials than the low contrast trials. The main effect of ISI on performance was significant [Wilks's Lambda = .162, F (3,49) = 84.657, p< .01, eta^2 = .838]. Participants tended to recall fewer letters as the ISI was increased. The main effect of age group was significant [F (2,51) = 47.777, p <.01, eta^2 = .652], with both young groups recalling more letters than the old group.

Within the young (150 ms) group, paired sample t-tests revealed that for each ISI increment (i.e., 0 ms to 50 ms), partial report letter recall significantly declined under both contrast conditions. Within the young (30 ms) group, paired sample t-tests revealed that for most ISI increments, letter recall significantly declined under both contrast conditions. The only exception was the increment between the low contrast increment from 150 ms to 300 ms, where there was no significant difference between means [t (17) = .52, p = .610]. Within the old (150 ms) group, paired sample t-tests revealed that none of ISI increments significantly decreased partial report performance. While no incremental change was significant, mean scores did decline with each longer ISI (except for the low contrast condition increment from 150 ms to 300 ms, where letter recall increased).

The young (150 ms) group recalled more letters, on average, in the high contrast partial report trials than in the low contrast trials. However, not all of the differences were significant. The high-low comparison for the 0 ms ISI was nonsignificant [t (17) =.22, p = .831], and the high-low comparison for the 300 ms ISI was nonsignificant [t (17) = 1.90, p = .074]. Within the young (30 ms) group, letter recall did not differ significantly in the two contrast conditions, with one exception. The high-low comparison for the 150 ms ISI was significant (t (17) = 2.18, p = .044). Within the old (150 ms) group, none of the high-low comparisons were significant.

Row Effects

Table 6 summarizes the average number of letters recalled in each row for the partial report procedure, collapsed across the two contrast conditions. A repeated measures ANOVA revealed a significant interaction of group by row [Wilks's Lambda = .774, F (4,100) = 3.417, p< .01]. The main effect of row was significant [Wilks's Lambda = .234, F (2,50) = 81.807, p< .01]. Sheffe's comparisons revealed that the young groups recalled significantly more letters in each row than the old group. Within group comparisons were conducted to determine the distribution of letters per row. Within the young (150 ms) group, participants recalled significantly more letters in the middle row than the top row [t (17) = -6.28, p <.01] or in the bottom row [t (17) =9.92, p <.01]. The average number of letters recalled in the top row and bottom row did not differ [t (17) = 1.09, p =.290]. Within the young (30 ms) group, participants recalled significantly more letters in the middle row than the top row [t (17) = -3.54, p <.01] or the bottom row [t (17) = 9.64, p <.01]. The average number of letters recalled in the top row and bottom row differed significantly [t (17) = 2.81, p <.01]. Within the old (150 ms) group, the average number of letters recalled in the top row did not differ significantly from the average number of letters recalled in the middle row [t (17) = -1.51, p =.149]. However, significantly more letters were recalled in the top row than in the bottom row [t (17) = 4.48, p <.01], and in the middle row than in the bottom row [t (17) = 5.27, p <.01].

Table 6

Letters recalled in each row as a function of group.

Row	Mean (Std. Dev.)		
	Young (30 ms)	Young (150 ms)	Old (150 ms)
Top	2.11 (.50)	1.95 (.38)	1.27 (.60)
Middle	2.51 (.25)	2.46 (.23)	1.63 (.57)
Bottom	1.75 (.49)	1.88 (.30)	0.74 (.52)

Note. Values represent the letters recalled in each row, collapsed across the two contrast conditions.

Predictor Variables

Two sensory measures (visual acuity and contrast sensitivity) and two cognitive measures (word fluency and processing speed) were collected in an attempt to predict age-differences in the iconic memory. As contrast was shown to have little effect on letter recall in the partial report, the PR and PRS scores at each ISI were collapsed into composite variables across contrast levels. Table 7 summarizes the Pearson correlations for the entire subject pool. When considering the relationship of the predictor variables and the outcome variables, it became evident that the sensory variables, CSF and visual acuity, and the cognitive variable, processing speed, reliably predicted whole report, partial report, and partial report superiority scores, regardless of ISI or contrast. Word fluency did not predict performance. Age was significantly correlated with each measure, except word fluency. Old adults tended to have poorer visual acuity, contrast sensitivity and slower processing speed than young adults. Intra-group correlations, however, indicated a different picture (see Appendix E and F). Within the two young groups, none of the predictor variables were significantly correlated with any of the iconic memory measures; furthermore, within the old group, none of the predictor variables consistently correlated with any of the iconic memory measures.

Table 7

Correlations between iconic memory variables and the predictor variables.

Variable	Age	CSF	Visual Acuity	Fluency	Process Speed
1. WR	-.657**	.437**	-.494**	.090	.477**
2. PR 0	-.840**	.478**	-.602**	-.124	.576**
3. PR 50	-.809**	.464**	-.576**	-.086	.576**
4. PR 150	-.718**	.443**	-.582**	-.025	.484**
5. PR 300	-.772**	.445**	-.574**	-.018	.501**
6. PRS 0	-.752**	.391**	-.525**	-.221	.500**
7. PRS 50	-.684**	.353**	-.470**	-.178	.481**
8. PRS 150	-.585**	.337*	-.503**	-.106	.368**
9. PRS 300	-.569**	.270*	-.417**	-.119	.319*

Note. The variables WR, PR 0 through PR 300, and PRS 0 through PRS 300 are composite variables found by taking the average of the letters recalled, across contrast conditions. Visual Acuity values are derived from the Bailey-Lovie Visual Acuity chart (the lower the score, the higher the acuity). Processing speed values are derived from the Salthouse Pattern Comparison task (the higher the score, the higher the processing speed). Fluency values are derived from the F-A-S Word Fluency task (the higher the score, the higher the fluency). One asterisk indicates significance at the .05 level. Two asterisks indicate significance at the .01 level. N = 54.

Discussion

In this study, three questions were addressed. The first question was do young and old adults differ in the capacity and duration of their iconic memory storage? The second was would changes in the quality of the visual image influence letter recall more in the old participants than the young participants? And the third was would longer stimulus durations allow the young participants more opportunity to recall letters than shorter durations?

Summary of Findings and Interpretations

The first major finding was that iconic memory could be reliably measured in the older population using a partial report procedure with visual cues. Many authors, such as Salthouse (1976) and Coyne et al. (1987), have questioned whether attentional and processing speed deficits prohibit older adults from successfully performing the partial report task. Sperling (1960), however, suggested that iconic memory is being tapped if performance on the partial report is superior to performance on the whole report. The results of this study revealed that both the young and the old participants could demonstrate partial report superiority, at least at the shortest inter-stimulus interval (ISI).

The results of this study replicated previous findings that partial report superiority declines as the length of the ISI increases (e.g., Gilmore, Allan & Royer, 1986; Gegenfurtner & Sperling, 1993). Generally, both groups of participants recalled more letters when the ISI was short (i.e., 0 or 50 ms ISIs) than they did when the ISI was long (i.e., 150 or 300 ms ISIs). The older participants found it particularly difficult to recall letters at longer cue delays. In fact, after cue delays of only 50 ms, letter recall by the older participants fell to whole report levels. It appears that the cue only facilitated letter recall when it appeared immediately after the letter matrix was removed.

In addition, it seems that the capacity of the icon to maintain information declines with old age. This suggestion was evidenced by the fact that young participants were able to recall a greater number of letters under all conditions than were the older participants. However, the conclusion that capacity declines with old age is subject to interpretation. Young adults were able to recall letters from all three of the rows in the matrix. Older participants, however, were successful in recalling letters from the top and middle rows only. Apparently, the older participants either did not "see" the bottom row when the letter matrix was on the screen or, when the cue signaled the bottom row, they could not shift their attention to it quickly enough to recall many of the letters (e.g., Salthouse, 1976).

However, the results do not definitively support the conclusion that young and old adults differ in the capacity and duration of iconic memory. When looking at these results in conjunction with past findings (i.e., Gilmore, Allan and Royer, 1986; Coyne et al., 1987), one conclusion can be suggested. It appears old adults require more time than young adults to fully develop the icon. At a stimulus duration of 50 ms, older adults could not show partial report superiority (Coyne et al., 1987). At 150 ms, they could show partial report superiority but only at the shortest ISIs (i.e., 0 ms). At 200 ms, however, they were able to demonstrate superiority at ISIs as long as 150 ms (Gilmore, Allan and Royer, 1986).

It appears that age differences in partial report performance are at least partially caused by changes in the speed of icon development. The icon may also have decreased capacity and fade faster once formed. The younger adult's icon may be fully developed within 30 ms of viewing the stimulus, whereas the older adult may require upwards of 200 ms viewing time to achieve a complete iconic representation. Therefore, unless the researcher can be reasonably confident that the icon has fully developed, inferences about capacity, or duration, should not be made. Future research should systematically examine age differences in iconic formation.

The second question addressed in this study concerns the effect of the quality of the physical visual image on formation of the icon. It was believed that low contrast letters would lead to weaker iconic representations; hence, letter recall would suffer. Enhanced, high contrast letters, on the other hand, should lead to stronger icons and greater letter recall. In fact, it was thought the differences between the young and old participants in partial report performance would be minimized under high contrast conditions. However, that was not the case. The high contrast letters did not augment letter recall for the older participants, and may have actually hurt performance. On several instances, letter recall by the older participants was better when the contrast was low. Consider, for example, the average partial report superiority at 0 ms ISI for the old group. Under high contrast conditions, the mean was .66, whereas under low contrast conditions, the mean was .73. At the 300 ms ISI, the difference in partial report superiority favored the low contrast by almost a third of a letter.

However, when looking at the components of the PRS score, this result becomes less pronounced. In fact, it reverses itself for several of the conditions. Older adults recalled more letters, on average, in the whole report when the contrast was high. They also recalled more letters in the partial report trials under high contrast conditions at 0, 50, and 150 ms ISIs. Therefore, if one considers the raw data scores, and ignores the PRS difference scores, it appears that the high contrast did facilitate performance. Significant main effects of contrast where found for both the whole report and partial report scores. However, the main effect of contrast on PRS was nonsignificant and was quite weak.

The young groups demonstrated similar trends. Partial report superiority scores were often higher on low contrast trials than on high contrast trials. And yet, whole report and partial report raw data were greater under high contrast than low contrast. In addition, consider the correlations between the high and low contrast trials. Correlations in the order of .77, some as high as .89, strongly suggest that contrast played a very small role in letter recall. The contrast of the visual image appears to have little to do with the formation of the icon, at least to the extent of image degradation used in this study.

There are some possible explanations for the lack of a contrast effect. First, the trials were grouped based on contrast, and before switching contrast levels, participants took a short break. Therefore, it is possible, even likely, that the participants quickly adapted to whatever particular contrast level they faced. Second, the difference between the two levels of contrast may not have been sufficient to produce a change in performance. The high contrast letters were quite bright, producing an almost one-hundred percent contrast to the black background. The low contrast letters, in comparison, were considerably dimmer, producing only about a 45 percent contrast to the background. And still, both sets of letters were clearly supra-threshold. In fact, given the high correlations between high and low contrast trials, it is possible that most participants were not at all challenged by the low contrast trials.

The third question addressed by this study was the effect of stimulus duration on letter recall within the younger sample. In an earlier study by Gilmore, Allan, and Royer (1986), it was suggested that processing speed differences meant that old adults required more time to form an iconic representation than young adults. In fact, Gilmore and his colleagues believed that stimulus durations of 200 ms would be required for the older participants, whereas 30 ms for the young participants would be sufficient.

In this study, one group of young participants were allowed the same amount of time as the old participants to view the letter matrices, 150 ms. A second group was allowed only 30 ms to view the letter matrices. It was believed that the group given more time should recall more letters than the other group. Contrary to the author's expectations, though, the results from this study suggested that stimulus duration made little difference in terms of the number of letters recalled by the participants.

The two young samples did not differ significantly on any of the dependent measures (average whole report, partial report, or partial superiority scores). Generally, the group tested at 30 ms had higher averages than the group tested at 150 ms on the low contrast trials, while the group tested at 150 ms had higher averages on the high contrast trials. However, since none of these differences were significant, a conclusion should not be drawn that one group benefited more from one level of contrast than the other did. This finding has important implications for iconic memory research. Formation of the icon appears to occur very rapidly within young adults. Based on the results of this study, one could speculate that once the icon has been formed, additional time does not add to, or strengthen, the original icon.

The results of this study have shown that advancing age has a detrimental effect on a person's ability to recall information from briefly presented stimuli, particularly if there is a delay between stimuli offset and recall. Correlations obtained in this study suggest that declines in visual acuity and contrast sensitivity, and declines in processing speed, may be responsible for the negative effects of age. Determining the course of change however is complicated by the inter-relatedness of the cognitive and sensory processes. One scenario might be as follows: As a person ages, his or her visual ability worsens and processing speed slows. These changes, in turn, lead to decreased ability to perform tasks such as the whole report and the partial report. Poor performance on these tasks, then, suggests that the iconic memory of older adults might not last as long, or hold as much information, as the iconic memory of younger adults. Another scenario might be that the duration and capacity of iconic memory does decline in older adults. Age might, as Baltes and Lindenberger (1997) have suggested, cause multiple and distributed changes in a person's sensory and perceptual ability, including diminished iconic memory. Future research will need to further examine the time course and path of age changes.

Conclusion

This findings of this study have demonstrated that younger adults recall more letters from briefly-presented letter matrices than do older adults. This finding was demonstrated when the younger subjects were allowed equal viewing time and when they were allowed only a fraction of the time that older subjects were given to view the stimulus. This study produced mixed results in terms of the effects of stimulus contrast on performance. In some instances, high contrast stimuli may have facilitated letter recall; in other instances, it may have hurt performance. Therefore, any conclusions about the effects of stimulus contrast will be held until further research is conducted.

As a person grows older, his or her ability to form, maintain and access information from iconic memory changes. Results from this study and from past research suggest that older adults require more time to form a complete iconic representation of the visual image. In addition, age dependent changes in visual ability and processing speed are intricately related to the declines in partial report performance demonstrated by older participants. Therefore, until researchers can partial out the changes in visual ability, in processing speed and in icon formation, definitive conclusions about age-related declines in iconic memory should be reserved.

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Appendix A: Informed Consent (Adult)

Project Title: Age differences in iconic memory.
Investigator: Andrew Scott LaJoie, Dept. of Psychology
RM. 223 Tate Page Hall
Western Kentucky University
502 745-5250.

You have been invited to participate in research being conducted by Andrew S. LaJoie, Master's candidate, of Western Kentucky University. For your participation, you will receive $10.00. The purpose of the research is to further existing knowledge about short-term memory. By undertaking this study, we hope to better understand some of the underlying factors which contribute to age-related changes in a certain type of short-term memory, called iconic memory.

In this study, you will be asked a few simple background questions and be given two standard vision tests. The primary task of this study will consist of you being shown blocks of nine letters on a computer monitor and reporting the letters you have seen. This task contains many trials and you may become tired. If so, feel free to take a short-break whenever you believe it necessary.

Any information collected in this study will be kept confidential and organized so that all information will remain anonymous. If you wish, the overall results of this study will be available to you in a written report. We cannot, however, provide you with your individual results. You have the right to withdraw from the study at any time. This study has met stringent requirements set by the Western Kentucky University Committee for the Protection of Human Research Participants. If you have any questions about your rights as a participant, you may contact the chair of the University committee, Dr. Jay Sloan at 745-4981, or the faculty advisor of this project, Dr. David Frieske at 745-4421.

I hope you enjoy taking part in this study. If you understand and agree with the information provided above, and give your consent to be a participant in the study, please sign your name and fill in the date below.

____________________________ ____________________

Participant's name Date

____________________________ ____________________

Experimenter's name Date

Appendix B: Informed Consent (Student)

Project Title: Age differences in iconic memory.

Investigator: Andrew Scott LaJoie, Dept. of Psychology
RM. 223 Tate Page Hall
Western Kentucky University
502 745-5250.

You have been invited to participate in research being conducted by Andrew S. LaJoie, Master's candidate, of Western Kentucky University. For your participation, you will receive extra course credit. The purpose of the research is to further existing knowledge about short-term memory. By undertaking this study, we hope to better understand some of the underlying factors which contribute to age-related changes in a certain type of short-term memory, called iconic memory.

In this study, you will be asked a few simple background questions and be given two standard vision tests. The primary task of this study will consist of you being shown blocks of nine letters on a computer monitor and reporting the letters you have seen. This task contains many trials and you may become tired. If so, feel free to take a short-break whenever you believe it necessary.

Any information collected in this study will be kept confidential and organized so that all information will remain anonymous. If you wish, the overall results of this study will be available to you in a written report. We cannot, however, provide you with your individual results. You have the right to withdraw from the study at any time. This study has met stringent requirements set by the Western Kentucky University Committee for the Protection of Human Research Participants. If you have any questions about your rights as a participant, you may contact the chair of the University committee, Dr. Jay Sloan at 745-4981, or the faculty advisor of this project, Dr. David Frieske at 745-4421.

I hope you enjoy taking part in this study. If you understand and agree with the information provided above, and give your consent to be a participant in the study, please sign your name and fill in the date below.

______________________________ ____________________

Participant's name Date

______________________________ ____________________

Experimenter's name Date

Appendix C: Instructions script for Experimenter (verbatim)

Greet the subject and have him or her read and sign the consent form.

"Here are two identical copies of my consent form. Take a few minutes to read one carefully. When you finish, sign & date both. Give one to me for my records and keep the other." "You can request a break at any time during the testing, but once we turn the lights down, I would like for you to stay in the lab for about 40 minutes. By keeping you in the room, your eyes will remain adjusted to the dim light. If you need to use the rest room or get a drink, now is a good time to do so. " Seat the subject 30 inches from the screen. Turn the lights down.

F-A-S task

Tell the subject "Read the instructions on the screen carefully. You will see a letter on the screen. Verbally tell the experimenter as many words beginning with the letter as you can. You will have one minute ." Count the number of words the subject recalls, making sure not to count words said more than once. After the minute is up, prompt the subject to press any key to continue to the next letter.

Whole Report task

Make sure to have the correct scoring sheet (whole report cue sheet) and a highlighter. Open the appropriate program (w-g, g-w). Show them the sample white letter matrix and then the sample gray letter matrix. "Read to me each letter of this matrix. Okay, now this one." "Hit any key to continue." Prompt them to read the instructions on the screen carefully.

Partial Report task

They might wish to stand up and move around some, but try to keep them in the darkened room. If they do need to go, have them sit in the darkened room for two minutes upon returning. "Make sure to read the instructions on the screen carefully." Take a short break between the two contrast conditions. Save the participant's file as a text file with the appropriate label (w or g) and open a new file for the second set of trials. Make sure to save the participant's file as a text file. After completing the second block of trials, turn the lights back on - warn the subject you are going to do so! Once the lights are on, the subject can leave the room if needed. Have the subject fill out the biographical questionnaire and subject information form.

Pattern Comparison task

Tell the subject, "In this task, you should determine whether the two patterns of lines are the same or different. If they are the same, write the letter s on the line between them. If they are different, write the letter d on the line. Try the example on the first page." "There are three sections on this task, and each section has two pages. Please complete the entire section, but do not move to the next section until instructed to do so. You will have 30 seconds for each section."

Shipley Vocabulary scale

Tell the subject "In this task, circle the lowercase word which is most similar to the word printed in capital letters. If you do not know the correct answer, guess. For instance, in the example, the word most similar to 'large' (and the word you would have circled) is 'big'."

Visual Acuity scale

Administer the Visual Acuity scale. Have the subject stand on the 2nd taped line, turn the lights on, and have him or her read from the third line down (left to right). Cross out the letters the subject incorrectly states and stop them when they've missed three or more letters.

Contrast Sensitivity scale

Administer the Contrast Sensitivity scale. To measure CSF, stand the subject about 40 inches (1st taped line) from the chart and ask them to read each line of letters from left to right. Mark through incorrectly answered letters on scoring sheet. Have them continue until they've incorrectly stated 2 of the 3 letters in the triplet. Tell the subject "Please wear any visual aides you would normally wear for reading. Read each row of letters, and keep going until I tell you to stop. When the letters become so faint that you don't think you can still see them, I'd like you to guess."

Thank the subject, tell them that their check will be mailed to them in about two weeks, or have them sign an extra credit sheet and write their professor's name. If they don't get their check, have them call me at 745-5250. If they wish for a copy of the results, tell them a summary will be sent as soon as possible. Send them on their way.

Appendix D: Study questionnaire

Please provide the following information:

Age in years: ____________ Gender (circle one): Male Female

Marital status (circle one): Single Married Divorced Widowed

Occupation (if retired, indicate so and give former occupation): ____________________

Ethnic background (optional): ___________________________

Education (check the highest level completed):

____________ Elementary or Junior High ____________ 2 or 4 Year College

____________ High School or GED ____________ Graduate School

How would you rate your overall health? (circle one) Excellent Good Fair Poor

How would you compare your health to others your age? Better Same Worse

Do you wear glasses or corrective lenses to help you see properly? Yes No

Do you have difficulty seeing at night? Yes No

If yes, does it restrict your activity or mobility? Yes No

Indicate below any visual aides you use, or visual problems for which you've been treated:

	YES	NO
Reading glasses	____	____
Bifocals	____	____
Glaucoma	____	____
Macular degeneration	____	____
Cataract	____	____
Scotoma	____	____
Other (please write in)	___________________________________	

If you know of someone who might be interested in participating in this study or in future studies of this nature, please provide their name, phone number and approximate age:

Name: ____________________________ Phone: ____________________ Age: _____

Name: ____________________________ Phone: ____________________ Age: _____

Name: ____________________________ Phone: ____________________ Age: _____

Appendix E: Selected correlations for the young participants

Pearson correlations for selected variables.

Variable	Age	CSF	Visual Acuity	Fluency	Process Speed
1. WR	-.006	.094	-.212	.230	.153
2. PR 0	-.304	.083	-.086	.286	.034
3. PR 50	-.293	.243	-.079	.204	.148
4. PR 150	-.224	.169	-.267	.189	.095
5. PR 300	-.304	.083	-.086	.286	.034
6. PRS 0	-.253	.094	.008	-.012	-.091
7. PRS 50	-.326	.197	.084	.042	.042
8. PRS 150	-.298	.151	-.188	.068	.003
9. PRS 300	-.388*	.015	.095	.146	-.105

Note. The variables WR, PR 0 through PR 300, and PRS 0 through PRS 300 are composite variables found by taking the average of the letters recalled, across contrast conditions. Visual Acuity values are derived from the Bailey-Lovie Visual Acuity chart (lower the score, the higher the acuity). Process speed values are derived from the Salthouse Pattern Comparison task (higher the score, the higher the process speed). Fluency values are derived from the F-A-S Word Fluency task (higher the score, the higher the fluency). One asterisk indicates significance at the .05 level. Two asterisks indicate significance at the .01 level. n = 36.

Appendix F: Selected correlations for the old participants

Pearson correlations for selected variables.

Variable	Age	CSF	Visual Acuity	Fluency	Process Speed
1. WR	-.128	.173	.373	.526*	-.174
2. PR 0	-.132	.001	-.021	.178	-.052
3. PR 50	.185	-.168	.152	.116	.026
4. PR 150	.080	-.009	.072	.202	-.123
5. PR 300	-.132	.001	-.021	.178	-.052
6. PRS 0	.092	-.150	.063	-.151	.221
7. PRS 50	.263	-.266	-.011	-.123	.112
8. PRS 150	.159	-.096	-.098	-.017	-.062
9. PRS 300	-.053	-.127	-.300	-.191	.071

Note. The variables WR, PR 0 through PR 300, and PRS 0 through PRS 300 are composite variables found by taking the average of the letters recalled, across contrast conditions. Visual Acuity values are derived from the Bailey-Lovie Visual Acuity chart (lower the score, the higher the acuity). Process speed values are derived from the Salthouse Pattern Comparison task (higher the score, the higher the process speed). Fluency values are derived from the F-A-S Word Fluency task (higher the score, the higher the fluency). One asterisk indicates significance at the .05 level. Two asterisks indicate significance at the .01 level. n = 18.