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Aging and Spatio-temporal Vision: Effects of Blur on Localization Task Performance

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Aging and Spatio-temporal Vision: Effects of Blur on Localization Task Performance

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Effects of Blur on Localization Task Performance

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The aim of this project was to examine age-related declines in the processing of spatial frequency information. Some current theories of spatial vision state that humans process high spatial frequency information separately or differently from low spatial frequency information. There is also evidence that normal aging may affect the processing of some spatial frequencies more than others. Specifically, it has been proposed that older adults have deficits in their ability to process low spatial frequency information, and that older adults process visual information more slowly in general than young adults. Eight observers in each of three age groups were tested on a localization task. The spatial frequency content of distractors presented in the visual field was varied along with speed of presentation and clarity of the display. A progressive loss in the extent of the functional visual field was demonstrated. Results were consistent with the position that older adults experience declines in their ability to process temporal information, and that older adults do process visual information at a slower rate than young adults.

Chapter I

Introduction

Current theories of human visual information processing state that the human visual system processes spatial frequency information through different neural channels (Campbell & Robson, 1968; Graham & Nachmias, 1971). More specifically, these theories state that high spatial frequency visual information (fine detail) is processed separately from low spatial frequency information (general form and movement). Some authors have suggested that high spatial frequency information is processed via neural routes labeled sustained mechanisms, while lower spatial frequency information is processed via neural routes labeled transient mechanisms (Blakemore & Campbell, 1969; Kulikowski & Tolhurst, 1973; Legge, 1978).

Evidence exists that as humans age they experience declines in their ability to process certain types of visual information. Some experimental results suggest that an adult's ability to process both high spatial frequency information (sustained mechanisms) and low spatial frequency information (transient mechanisms) declines with age (Arden & Jacobsen, 1978). Other experimental results suggest the declines with age occur only with the processing of high spatial frequency information (Arundale, 1978; Derefeldt, Lennerstrand, & Lundh, 1979; Owsley, Sekuler, & Siemsen, 1983), or with the processing of temporal information (Sturr, Kelly, Kobus, & Taub, 1982; Walsh, 1976). In addition, other results show that older adults process visual information more slowly than younger adults (Kline, Schieber, Abusamra, & Coyne, 1983).

The purpose of this study was to compare the performance of older, middle, and younger aged adults on a task requiring the processing of both high and low spatial frequency information presented at various speeds. The present experiment, therefore, would provide more specific information on human visual system changes occurring with normal aging. In addition, the study directly addresed the question of the specificity of the aging change (i.e., high or low spatial frequency losses, or both). Finally, by varying presentation speed, the study addressed whether older adults process visual information at a slower rate than younger adults.

Based on past research, several hypotheses regarding the effect of aging on visual processing were generated. First, it was hypothesized that blurring the stimuli would degrade the performance of older adults more than younger adults. This hypothesis was based on the theory that older adults experience declines in the transient system. Secondly, it was also hypothesized that older observers would have more difficulty performing a peripheral localization task when the target was embedded in a field of low frequency distractors. Finally, it was hypothesized that older observers would have more difficulty performing the task at shorter exposure durations than younger observers, and that the older observers would experience more difficulty than younger observers when stimuli were presented at extreme ecentricities from fixation.

Chapter II

Literature Review

As stated previously, this study was conducted to determine changes that may occur with normal aging in the human visual system. Specifically, concerns were differential changes in older adults ability to process high and low spatial frequency information, and in their ability to process temporal information (movement). Spatial frequency refers to the number of pairs of bars imaged within a given distance on the retina, with the units of spatial frequency being cycles per degree (c/deg) of visual angle. The following is a discussion of literature showing differential response properties to low and high spatial frequency information. This will be related to the sustained/transient model of visual information processing and other changes that occur in the human visual system with normal aging.

Transient and Sustained Channels

Previous research has shown that the visual system may process spatial frequency information through different channels (Campbell & Robson, 1968; Graham & Nachmias, 1971). Numerous studies, both physiological and psychophysical, provide evidence for the existence of a transient/sustained dichotomy. There is physiological evidence that the visual system of lower animals may possess separate high and low spatial frequency processing systems. Ikeda and Wright (1974) took single-cell recordings from cat's cortical cells while the cat was exposed to grating patterns (a grating is a target consisting of alternating lighter and darker bars) of various spatial frequencies. They found that some cells were selectively responsive to gratings of higher spatial frequencies, and other cells were selectively responsive to gratings of lower spatial frequencies. Thus physiological evidence for separate visual information processing systems exists for cats. Enroth-Cugell and Robson (1966) measured the electrical activity in the cat's optic tract and found cells that responded to gratings of various spatial frequencies as the gratings were moved through the cat's visual field. Other cells did not respond to this movement. This indicated that some neural channels respond selectively to motion.

The human visual system may also process spatial frequency information through different neural channels. These spatial frequency processing channels have been labeled the transient channels and the sustained channels. Although no direct physiological evidence for separate visual information processing systems exists for humans, there is an abundance of psychophysical evidence for these separate systems. The transient channels are sensitive to targets of low spatial frequency, less than 1.5 c/deg

(Legge, 1978), and to rapid change, such as motion or flicker (von Grunau, 1978). They respond within 100 msec (Legge, 1978), and respond better to abrupt stimulus onset than the sustained channels (Green, 1981; Kline & Schieber, 1981). Williams, Brannan, and Lartigue (1986) have described the transient channels as functioning in detecting motion and localizing targets in space, and in directing eye movements toward the detected target. The transient channels may function more in peripheral vision, while the sustained channels may be more important in central visual field tasks.

The sustained channels, on the other hand, are sensitive to targets of higher spatial frequency, 1.5 c/deg and greater (Legge, 1978), and to stationary or slowly moving targets. The sustained channels respond best to targets presented at long durations, 1000 msec (Legge, 1978), and to finely patterned targets (Breitmeyer, 1978b; Kline & Schieber, 1981). The sustained channels function to identify patterns and to resolve fine detail once the eyes orient toward the target.

Psychophysical studies of the human visual system which have some bearing on the spatial frequency models of vision have involved measurement of contrast thresholds, speed of processing visual information, and studies involving visual masking and Critical Flicker Frequency (CFF). The following sections will discuss evidence that suggests transient and sustained channels process different spatial frequency information independently as well as evidence that suggests the two channels interact in processing different spatial frequency information. Also, evidence contrary to the existence of a transient/sustained dichotomy will be discussed.

Independent Transient/Sustained Channels

Studies supporting the existence of independent transient and sustained channels involve temporal processing and speed of processing.

Temporal Processing

Contrast sensitivity

In one test of the transient/sustained dichotomy, Breitmeyer and Julesz (1975) measured observers' contrast sensitivity (the reciprocal of contrast threshold) to sinusoidal gratings of variable spatial frequency under two conditions: abrupt onset/offset and gradual onset/offset. Contrast thresholds, and thus contrast sensitivity, are measured by asking the observer to determine the point at which he/she can first detect the presence of a grating. The abrupt temporal envelope of the gratings increased the observer's contrast sensitivity to gratings of lower spatial frequency, but had no effect on the detection of higher spatial frequency gratings. This supported the existence of the dichotomy. Pantle (1970) measured contrast sensitivity to a square-wave test grating with a spatial frequency of 0.38 c/deg drifting at speeds ranging from 0.0 (no motion) to 22 degrees per second after adapting to gratings ranging from 0 (uniform field) to 23 c/deg spatial frequency. When the test grating drifted at higher speeds, only lower spatial frequency adapting gratings elevated the contrast threshold of the test grating. When the test grating moved at slower speeds, the higher spatial frequency adapting gratings had an increased effect on the test gratings contrast threshold. Thus, both drift speed of the test grating and the adapting grating's spatial frequency can affect the contrast sensitivity of a lower spatial frequency test grating, indicating the presence of neural channels differentially sensitive to spatial frequency. The contrast sensitivity of lower spatial frequency gratings appears to be increased by abrupt stimulus onset and rapid movement, consistent with the sustained/transient dichotomy of human visual information processing.

Critical flicker frequency

Studies involving the detection of flickering gratings also provide support for specialized neural mechanisms. Tolhurst (1973), Kulikowski and Tolhurst (1973), and Keesey (1972) performed studies whose results suggested that flicker is processed by low spatial frequency channels. They found that observers could discern that gratings were flickering before they could provide information about the gratings spatial frequency. The less frequently the lower spatial frequency gratings were flickering, the less sensitive the observers were to the spatial frequency content of the grating. This suggests that neural channels processing lower spatial frequency information are more sensitive to flicker than to form. In addition, adaptation to flicker raised the detection threshold for low spatial frequency targets but not for high spatial frequency targets (Green, 1981). These studies indicate that the human visual system processes visual information via separate neural mechanisms. Specifically, channels processing low spatial frequency information also process movement, a function of proposed transient channels.

<u>Speed of Processing</u>

<u>Contrast sensitivity</u>

Nachmias (1967) and Breitmeyer & Ganz (1977) performed similar studies measuring the contrast thresholds of spatial frequency gratings ranging from 0.44 c/deg to 33.2 c/deg presented at various exposure durations. Both studies reported that as exposure duration of the test gratings decreased, contrast sensitivity also decreased, but more so for gratings of higher spatial frequencies. These results indicate a longer integration time for gratings of higher spatial frequencies. This is suggestive of mechanisms selectively sensitive to different temporal parameters, with lower spatial frequency information (transient mechanisms) encoded more quickly than higher spatial frequency information (sustained mechanisms). Furthermore, Breitmeyer (1975) and Vassilev & Mitov (1976) have found that observers have shorter reaction times to sinusoidal gratings of lower spatial frequencies, providing additional credence to the contention that proposed transient channels have shorter response times than proposed sustained channels.

Masking studies

Legge (1978) performed a masking study whose results suggested that the human visual system may require less time to process low spatial frequency information than high spatial frequency information. Masking refers to a reduction in stimulus visibility as a result of another, stronger stimulus preceding and/or following the original stimulus. Contrast thresholds were measured for various spatial frequency gratings presented at different exposure durations at the onset and offset of masking stimuli. For unmasked conditions, sensitivity to low spatial frequency gratings was independent of exposure duration at shorter exposure durations than for high spatial frequency gratings. This indicated that low spatial frequency information requires less time to be processed than high spatial frequency information. However, for masked conditions, sensitivity to low and high spatial frequency gratings remained approximately the same for all exposure durations, indicating that the masking stimuli may affect only the low spatial frequency gratings. This effect could be due to the abrupt onset of the mask (movement) inhibiting mechanisms processing low spatial frequency information (transient mechanisms).

Interactions between Transient/Sustained Channels

More recent investigations have cast doubt on the hypothesis that these neural channels process spatial frequency informatior independently in humans. Tolhurst (1972) adapted observers to square wave gratings before determining the individual contrast thresholds of the fundamental and third harmonic components of the square wave. A square-wave grating is composed of a fundamental sinusoidal grating of a particular frequency (e.g., 1 c/deg) added to all odd multiples of this frequency (e.g., 3, 5, 7, etc., c/deg) in peaks-add phase. These higher frequencies, or harmonics, are reduced porportionally in amplitude or contrast by the inverse of the spatial frequency (e.g., 1/3, 1/5, 1/7, etc., c/deg). He found the independent contrast thresholds of the third harmonic and fundamental components of the square wave grating to be less than predicted after adaptation to a square-wave grating. This suggested that spatial frequency channels subserving the fundamental and third harmonic frequencies inhibit each other when the patterns are suprathreshold. Thus, channels that process different spatial frequency information can be mutually inhibitory.

Von Grunau (1978) published results suggesting that sustained channels inhibit transient channels. In this study dark boxes were sequentially flashed dark boxes at inter-stimulus intervals of 0.0, 25, 50, 75, and 100 msec separated by 1, 2, and 4 degrees. He then defocused the flashed boxes to force the use of transient mechanisms by removing higher spatial frequency information from the stimuli. He found that defocusing the stimuli increased the perception of apparent motion in the foveal regions of the visual field, but not in the peripheral visual field. This suggested that defocusing the stimuli lessened the inhibition of the sustained channels on the transient channels, particularly in the foveal regions of the visual field, and that sustained channels' inhibition of transient channels is strongest in foveal regions.

Breitmeyer (1978a) presented results indicating that under some stimulus conditions transient channels inhibit sustained channels, while under other stimulus conditions sustained channels can inhibit transient channels. Breitmeyer (1978a) measured vernier foveal resolution (detection of vertical offset in the placement of bars) masked by flanking bars in the presence and absence of additional, stationary flanking bars separated from the mask by 4 and 20 degrees of visual angle. He found that the additional flanking bars at 4 degrees lessened the inhibition of the mask on the foveal vernier resolution task. Breitmeyer (1978a) suggested that the additional, stationary flanking bars activated sustained channels (necessary for detecting fine details) and caused them to inhibit transient channels activated by the mask. It thus appears that significant inhibitory interactions can occur between neural channels processing different spatial frequency information. The previously mentioned studies suggest some overlap in the functioning of the "transient" and "sustained" neural channels.

What is the basis for the differing experimental results regarding the transient/sustained dichotomy? Studies showing the independence of spatial frequency channels have usually tested stimuli near contrast threshold, while studies showing interactions of spatial frequency channels have usually tested suprathreshold stimuli. Therefore, before any statements about the independence of spatial frequency channels or any interactions among spatial frequency can be made, the contrast of the stimuli must be considered.

Evidence against the Dichotomy

Recent investigations have revealed that a strict dichotomy between pattern and motion (or flicker) detection systems is unwarranted (Derrington & Henning, 1981; Green, 1984; and Stromeyer, Klein, Dawson, & Spillman, 1982). Derrington and Henning (1981) required observers to discriminate between vertical and horizontal gratings of various spatial frequencies that either flickered or did not flicker. Observers had more difficulty discriminating between the horizontal and vertical gratings when they were not flickering, as opposed to when they flickered, suggesting that neural mechanisms relating information about flicker (motion) also relate information on pattern (form). Stromeyer, Klein, Dawson, and Spillman (1982) found that with low spatial frequency gratings (0.12 to 1.0 c/deg) maximal threshold elevations occurred when the adapting grating was the same spatial frequency as the test grating. These results were obtained using test patterns that turned on and off gradually, activating sustained mechanisms. These results suggested that some form mechanisms are optimally sensitive to low spatial frequencies.

Green (1984) has also disclaimed the transient/sustained dichotomy of neural processing of visual information, and proposed a model of visual information processing which states that all neural channels share the same response properties. He has proposed that all neural channels process both form and temporal information, but some channels predominantly process form information while others predominantly process temporal information. Thus, it is probably the case that channels thought of as "transient" or "sustained" share the same response properties, but that stimulus conditions dictate how each channel will respond.

An interest during the present study was differences that may exist in the processing of high and low spatial frequency information in the human visual system. More specifically, the concern was with differences that may develop with normal aging. Therefore a summary of literature related to aging and the visual system follows.

Aging and the Human Visual System

Many declines in visual functioning, unrelated to disease, have been reported for the human visual system. For example, Weale (1975) reports decreases in visual acuity after age 45. Reduced retinal illumination is also found in older eyes, with the 20-year-old eye transmitting roughly three times more light to the retina than the eye of a 60 year old (Weale, 1963). Furthermore, a survey by Kosnik, Sekuler, and Kline (1986) revealed that older adults report more difficulties seeing in poor illumination and performing tasks requiring rapid visual processing.

Walsh (1976) and Walsh, Till, and Williams (1978) performed masking studies using both older and younger observers. These studies measured the masking effects of straight lines on the detection of letters. They manipulated the time interval between the mask and the test stimuli and found that older subjects required a longer interval between the test stimulus and the masking stimulus to identify the letter, indicating a slower speed of processing for the older adults. Walsh (1976) found that the older subjects required a 24% longer interval between the mask and test stimuli to escape the effects of masking for stimuli presented in the central visual field. Kline and Szafran (1975) and Kline and Birren (1975) have also performed masking experiments which indicated that older adults require more time to process visual information.

Wolf (1963) has suggested that older adults have impaired abilities in visual tasks requiring peripheral vision. Wolf and Nadroski (1971) measured the sensitivity of younger, middle aged, and older subjects visual fields and found that older subjects saw significantly fewer targets in the peripheral visual field than younger subjects. Scialfa, Kline, and Lyman (1987) found older adults were less accurate in identifying letters presented in their peripheral visual field than younger adults, especially when the letters were embedded in visual noise. Their results suggest older adults have a lower scan rate and a reduced field of vision compared to younger adults. Ball (1985) has also found that older adults perform more poorly on a peripheral localization task than do younger adults.

Aging and Transient/Sustained Shifts

Age may also differentially effect the processing of high and low spatial frequency information. Kline and Schieber (1981) have proposed that the aging visual system experiences a relative loss in the efficacy of the "transient" channels and becomes "sustained" dominant. This suggests that the "transient" channels lessen their inhibition of the "sustained" channels. Studies that have some relavence to this model of the aging human visual system involve the processing of both temporal and spatial frequency information.

Temporal Processing

Previous research has shown that older adults experience a decline in their ability to detect flicker (Huntington & Simonson, 1965; McFarland, Warren, & Karis, 1958), and have greater difficulty escaping visual masking (Walsh, 1976). This suggests that older adults have deficits in processing temporal information (a transient response), indicating a lessening of "transient" channel inhibition of the "sustained" channels.

Older adults also show a decline in rapid light adaptation (Sturr, Kelly, Kobus, & Taub, 1982; Sturr, Church, and Taub, 1985). After dark adaptation, younger and older observers were required to detect a small test flash superimposed on a large, intense background flash (transient condition). Older subjects required a longer time to adjust to the long intense flash, hampering their ability to detect the test flash. When younger and older subjects were allowed to adapt to the lighted condition (steady state or sustained condition), no difference existed in the younger and older observers' ability to detect the test flash. Sturr, Church, Nuding, Van Orden, and Taub (1986) found this effect to be independent of the luminance level of the large, intense flash. Owsley, Sekuler, and Siemsen (1983) found that drifting low spatial frequency gratings resulted in an increased sensitivity for younger observers, but not for older observers, suggesting temporal processing impairments for older adults. The above results consistently indicate that older adults may experience declines in temporal, "transient" type visual functioning, which is consistent with the model proposed by Kline and Schieber (1981).

Spatial Frequency

Other experimental results contradict the transient/sustained shift model of aging (Kline and Schieber, 1981) by suggesting that older adults have difficulty processing higher spatial frequency (form) information. Owsley, Sekuler, and Siemsen (1983) found that older observers had decreased sensitivity to high spatial frequency gratings. Arundale (1978) measured the contrast sensitivity of older and younger observers' and found that older subjects' peak sensitivity occurred at lower spatial frequencies than younger subjects. Derefeldt, Lennerstrand, and Lundh (1979) found older observers to be less sensitive to middle and higher spatial frequency gratings than younger observers. Kline, Schieber, Abusamra, and Coyne (1983) reported that older observers are less sensitive to higher spatial frequency gratings even though older observers required more time to process the visual information. Thus, it appears that older adults experience declines in their ability to process high spatial frequency information, which is inconsistent with the results predicted by the model of Kline and Schieber (1981). However, these results may not be inconsistent if the evidence supporting shared response properties among spatial frequency channels is incorporated into Kline and Schieber's (1981) model.

It seems unclear exactly what types of declines older adults may experience related to visual information processing; however, most evidence suggests that older adults experience declines in temporal processing, "transient" type visual functioning, and in processing high spatial frequency information. Burbeck (1986) and Post and Liebowitz (1980) conducted studies that potentially shed light on this question. Burbeck found that a peripheral target's spatial frequency content could affect localization accuracy for that target. More specifically, she found that accurate peripheral localization of high spatial frequency targets required more time than localization of low spatial frequency targets. This is consistent with the temporal response properties of spatial frequency channels. Post and Leibowitz (1980) measured localization accuracy of single, flashed dots for both blurred and unblurred conditions, and found no differences in observers' localization accuracy between blurred and unblurred conditions. Since blurring defocuses stimuli, causing sharp edges to become fuzzy, it effectively lowers the spatial frequency content of a stimulus. However, the actual spatial frequency content of the targets never varied in this study, and there were no distractors present in the test field to test for inhibition. Also, neither Burbeck (1986) nor Post and Leibowitz (1980) compared older subjects' performance on these tasks to that of younger subjects' performance. Comparing older and younger subjects' performance on tasks similiar to those of Burbeck (1986) and Post and Leibowitz (1980), where the spatial frequency content of peripheral localization targets varied, could detect differences that exist between older and younger observers' ability to process higher and lower spatial frequency information. This could point out age dependent differential declines in "sustained" or "transient" neural channels.

Sekuler and Ball (1986) developed a perimeter test which required observers to localize peripherally presented oval faces hidden among box-like distractors while performing a concurrent central task. Their task consisted of localizing a cartoon likeness of a face that appeared equally often, but unpredictably in each of 24 different peripheral locations: along eight meridia (four cardinal and four oblique) at three different eccentricities (5, 10, 15 degrees) from the display center. Distraction consisted of 47 outline boxes of the same size that occupied the remaining 23 positions plus intermediate positions. In conditions where observers had to perform a concurrent central task while localizing the peripheral face among distractors, older observers exhibited higher localization error rates than younger observers, particularly at extreme eccentricities. This suggested a loss in the quality of peripheral vision among older adults. In conditions of no concurrent central task or peripheral distraction, both younger and older observers made few localization errors. With practice, the older observers increased the extent of their functional visual field by 50%, indicating that training reduces visual field losses due to age.

Ball (1985) investigated the question of why distractors presented a problem for older adults. Using a localization task identical to that of Sekuler & Ball (1986), he measured younger, middle, and older aged observers' ability to localize both oval-shaped and box-shaped peripheral faces presented at exposure durations of

120 msec and 90 msec. Observers' were then trained on detecting either box or oval faces presented at 120 msec, and then retested on both box and oval faces presented at 120 msec and 90 msec. Initially, older observers performed more poorly on the localization task than did younger observers. Practice on either oval or box face targets improved performance on the practiced condition for all age groups. However, this improvement in performance transferred to the untrained target condition only for younger observers. Transference from 120 msec, trained conditions to 90 msec, trained conditions occurred for all age groups, but transference to 90 msec, untrained conditions did not occur at all. Ball (1985) therefore hypothesized that improvements in performance of older observers on trained conditions resulted from learning to ignore the irrelevant stimuli rather than a generalized increased speed of central processing.

However, Ball did not address the question of why younger observers exhibited fewer localization errors across all target types compared to older observers, even after practice, nor did he explain why the box face targets were harder to localize than the oval face targets. A modified version of Sekuler and Ball's (1986) localization task could answer this question, and shed light on age differences in processing higher and lower spatial frequency information or age dependent differential "sustained/transient" neural channel declines. If the model of Kline and Schieber (1981), which states that older adults have deficits in transient channels, is accurate, then older observers could be expected to be less accurate than younger observers on the localization task when forced to use their "transient" mechanisms to process visual information. This could be accomplished by varying the spatial frequency content of the distractor stimuli and blurring the display screen via positive lens (von Granau, 1978). Also, since Kline and Schieber (1981) hypothesized that aging lessens the "transient" channels inhibition on "sustained" channels, older subjects could be expected to exhibit more localization errors with decreasing test stimulus exposure time.

Hypotheses

Several hypotheses were tested. If older observers have deficits in transient mechanisms, then conditions forcing the use of these mechanisms should cause older adults to make more localization errors than conditions forcing them to use sustained mechanisms. Since blurring the stimuli would force the use of transient mechanisms, older observers would therefore be expected to make more localization errors under blurred conditions than under unblurred conditions. In addition, if transient deficits exist then older observers would be expected to make more localization errors with low spatial frequency distractors than with high spatial frequency distractors.

Previous studies suggest that older observers process visual information at a slower rate, in general, than younger observers. If so, then older observers should make differentially more localization errors at shorter exposure durations than at longer durations regardless of other stimulus conditions. If transient mechanisms process visual information more quickly than sustained mechanisms, then forcing observers to use their transient mechanisms should improve performance on the short exposure duration conditions. Lastly, it was hypothesized that as eccentricity increased all observers would make more localization errors, and that this effect would be more pronounced for the older adults.

Chapter III

Method

Observers

Eight observers were tested in each of three age groups. The young adults tested were in the 24-28 years age range (4 males, 4 females); middle aged adults ranged from 39-50 years (2 males, 6 females); and older adults ranged from 60-77 years of age (1 male, 7 females). This division of age groups allowed an evaluation of developmental changes throughout adult life.

Since this research concerned visual system changes related to the normal aging process all observers were screened for ocular pathology prior to their paticipation. Several eye diseases producing visual losses occur more frequently in later adulthood (Leibowitz, et al., 1980), and often difficulties arise when separating biological changes due to age from changes resulting from disease (Ludwig, 1980). Also, many older adults exhibiting no ocular pathology report visual problems (Kosnik, Sekuler, & Kline, 1986), and these adults were the focus of this experiment.

The following screening procedure was employed to gather information concerning all observer's eye health.

a. After contacting a person about participating in the research, an explanation of the study's nature and purpose was provided, specifically mentioning that the research's primary focus was visual changes occurring in later adulthood, and that only individuals with no eye disease history would be tested. Before initiating testing, a screening interview was conducted in which the potential participant was questioned about the presence of any type of eye disease (other than refractive error) indicated by an eye-care specialist. Macular diseases, glaucoma, cataracts, optic neuritis, and diabetic retinopathy were specifically mentioned. Potential observers were also questioned about their history concerning diabetes and neurological problems. If potential observers indicated they suffered from any of these problems, it was explained that they could not participate due to the experiment's nature and purpose, and they were thanked for their interest. A copy of the Subject Information Sheet used to record potential observer's answers is included in Appendix A.

b. If the interested potential observer reported no eye disease history, he/she was asked to read and sign an informed consent form. A copy of this form is included in Appendix B. The observer was informed of how many sessions would be required and three appointments were scheduled.

c. Each observers' acuity was measured near the experimental viewing distance, as a final health measure, to ensure that all observers had normal acuity for their age. Acuity measurements for distance (Ten feet) were obtained using a Baily-Lovie Distance Chart. Acuity measures for near distances (57 centimeters) were obtained using the Baily-Lovie Near Charts. Sinco all observers were required to perform tasks in blurred and unblurred conditions, each observer's acuity for near distances was also measured with the observer wea.ing lenses of +3.0 diopter optical power above normal correctd vision. The average near acuities (minimum angle resolvable) for the young, middle, and older age observers were .76, .80, and .88, respectively. The average near acuities (minimum angle resolvable) for young, middle, and older age observers while wearing the +3 diopter optical power lens were 1.28, 1.25, and 1.22, respectively. If corrective lenses were needed for best corrected acuity, the observer wore them during the experimental sessions. The +3 diopter lenses were clipped onto the observer's corrective lenses to blur the target images. If the observer did not wear corrective lenses, then the +3.0 diopter lenses were clipped into a pair of trial frames for the observer to wear.

To allow better interpretation of age differences, criterion free measures of sensitivity or discriminability were obtained by using a forced choice procedure. Observers were required to make a response following each presentation, eliminating any differences due to varied criteria.

Stimuli

The test stimuli resembled those used by Sekuler and

Ball (1986). A box (which was a square shape) outline of 0.0171 footcandles luminance with no internal detail subtending 2.25 x 4.5 degrees served as the peripheral target. This box appeared unpredictably, but equally often, in each of 24 different positions on a 135 cm x 135 cm video screen (90 x 90 degrees) under computer control. The 24 positions were along eight meridia (four cardinal meridia and four intermediate, oblique meridia) at three different eccentricities (7.5, 15, or 22.5 degrees). These eccentricities were different from those used by Ball (1985) and Sekuler and Ball (1986) because the viewing distance was adjusted (which changed the target eccentricities) to keep the frames of the trial lens from obstructing the observers view of the video screen.

Distractor stimuli were cartoon likenesses of human faces of 0.016 footcandles luminance subtending 2.25 x 4.5 degrees on the screen in one condition, or outline oval faces of 0.0131 footcandles luminance with no internal detail in another condition. The concurrent central task consisted of an additional face (identical to the cartoon faces with internal detail) which was present or absent in the center of the fixation box.

Procedure

Observers were seated with their heads positioned in a chin rest 42.75 cm from the display screen. Their eyes were level with the screen and viewing was binocular. At this viewing distance, 1 cm on the screen represented 1.5 degrees of visual angle. Prior to beginning the experiment, each observer was familiarized with the required task and given a chance to ask questions about the experiment. During the experiment, the room was dimly lit, and stimuli were presented against a dark background.

Each trial consisted of four successive displays controlled by a computer. First, an outline box (6 x 7.5 degrees) directed the observer's fixation to the center of the screen. After one second, the test stimulus appeared on the screen for either 75, 100, 125, or 150 msec. These exposure durations were used to span the range, as indicated by an informal pilot study, where young observers would have difficulty performing the localization task on short durations, but where all observers could perform the localization task moderately well at longer durations. After this, the entire display was replaced by spatially random visual masking noise to cover any residual afterimages on the screen. The figural characteristics of the mask should not have interfered with the ability of observers to localize the peripheral target stimuli (Turvey, 1975). Finally, after one second, a radial pattern appeared with eight equally spaced spokes numbered 1 to 8. This pattern remained until the observer made a radial localization response by selecting one of the eight numbers located on a keypad in front of him/her. Trials were grouped in sets of 24, one trial with the peripheral target at each of its 24 possible positions.

The observer made two responses at the end of each trial. First, the observer indicated if the central face was present or absent by pushing one of two buttons on a keypad. Next, the observer indicated the radial locality of the peripheral box by pushing one of eight numbered buttons on the keypad. If the observer provided an incorrect central response no additional responses were permitted. Computer generated tones provided the observer with immediate feedback on the correctness of his/her response. Any terminated trials were re-presented later in the block of trials.

Two distractor conditions were employed. In the first condition the box, as the target, was accompanied by 47 cartoon human faces (filled faces, which had two dots for eyes and a line for a mouth) of the same size as the target box. These distractors occupied all possible remaining box positions and three positions between the eight meridia. In the other distractor conditions, the stimuli were the same except the cartoon human faces were replaced by the outline oval faces with no internal detail (unfilled faces).

Observers also viewed the two conditions under two levels of clarity. At the first level the observer viewed all 24 trials of a condition at his/her best corrected acuity. At the second level, the observers viewed the 24 trials through lens of +3.0 diopters optical power to slightly blur the images, eliminating some of the high spatial frequency information from the images.

There were thus four different combinations of distractor and clarity levels: filled faces/blurred images; filled faces/normal images; unfilled faces/blurred images; and unfilled faces/normal images. Each observer viewed each of the four combinations at the previously mentioned exposure times of 75, 100, 125, and 150 msec. This resulted in each subject completing 16 blocks of 24 trials. Each observer viewed all four of the distractor/clarity level combinations in a random order, and each distractor/clarity level combination was viewed randomly at each of the four exposure times.

The 16 blocks of 24 trials were presented to participants over three consecutive days. On the first day, the observer practiced the task for a brief period to familiarize him/herself with the task, and then completed the first four blocks of 24 trials. On the second day, each observer completed six more blocks of trials, followed by the remaining six blocks of trials on the third day. All observers received $6.00 per session for participation in the experiment to enhance their motivation to complete the experiment.

Chapter IV

Results and Discussion

The main focus of the study was on the distribution and number of errors made in radial localization. Errors were summed across the eight meridia and converted to percentages. The resultant proportions (percent errors) were normalized by taking the inverse sine of the square root of the percent errors for the purpose of statistical and graphical data analysis. On this scale, a transformed error score of 1.2 corresponds to chance performance (87.5% errors), .79 corresponds to 50% errors, and 0.0 corresponds to 0% errors.

Data were analyzed with a repeated measures ANOVA. Results are shown in Table 1. The only between groups variable was age, with clarity (blurred stimuli versus unblurred stimuli), distractor condition (filled faces versus unfilled faces), eccentricity (7.5, 15 versus 22.5 degrees), and speed (75 msec, 100 msec, 125 msec versus 150 msec) all repeated measures for each of the three age groups. A diagram of the experimental design is illustrated in Figure 1. Results will be discussed in the context of Kline and Schieber's (1981) model of the aging effect on the "transient/sustained" dichotomy of visual information

Table 1

ANOVA Summary Table

Source	df	SS	MS	F	p
Age (A)	2	82.662	41.331	21.94	.0000
Error	21	39.559	1.833		
Clarity (B)	1	.753	.753	4.60	.0438
B x A	2	1.339	.669	4.09	.0316
Error	21	3.437	.163		
Distractors (F)	1	1.524	1.524	8.54	.0081
F x A	2	.975	.488	2.73	.0881
Error	21	3.746	.178		
B x F	1	.069	.068	1.08	.3107
B x F x A	2	.593	.297	4.65	.0213
Error	21	1.339	.064		
Speed (S)	3	24.845	8.282	56.20	.0000
S x A	6	2.289	.382	2.59	.0263
Error	63	9.284	.147		

Source	df	SS	MS	F	p
B x S	3	.143	.048	.67	.5732
B x S x A	6	.212	.035	.50	.8072
Error	63	4.474	.071		
F x S	3	.387	.129	1.13	.3426
F x S x A	6	.561	.094	.82	.5581
Error	63	7.183	.114		
B x F x S	3	.095	.032	.38	.7649
B x F x S x A	6	.092	.015	.18	.9801
Error	63	5.222	.083		
Eccentricity (E)	2	13.818	6.909	47.82	.0000
E x A	4	.422	.105	.73	.5765
Error	42	6.069	.144		
B x E	2	.426	.213	5.81	.0059
B x E x A	4	.493	.123	3.36	.0178
Error	42	1.539	.037		
F x E	2	.039	.019	.38	.6834
F x E x A	4	.140	.035	.69	.6016
Error	42	2.130	.050		

Source	df	SS	MS	F	p
B x F x E	2	.024	.012	.31	.7374
B x F x E x A	4	.224	.056	1.41	.2457
Error	42	1.663	.039		
S x E	6	.656	.109	2.48	.0265
S x E x A	12	.877	.073	1.66	.0838
Error	126	5.551	.044		
B x S x E	6	.038	.006	.16	.9877
B x S x E x A	12	.661	.055	1.34	.2044
Error	126	5.178	.041		
F x S x E	6	.136	.022	.68	.6654
F x S x E x A	12	.510	.042	1.28	.2379
Error	126	4.183	.033		
B x F x S x E	6	.220	.037	.86	.5285
B x F x S x E x A	12	.331	.028	.64	.8004
Error	126	5.392	.043		

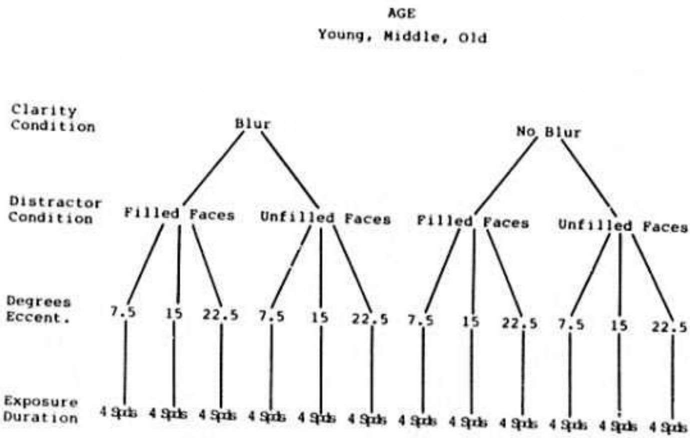

Figure 1. Schematic diagram of the experimental design

processing. In addition, the implications of these results for the conclusions of Ball (1985) will also be discussed.

In the review of literature concerning age related spatial frequency information processing in humans, it was hypothesized that older observers would have more difficulty processing low spatial frequency information than younger adults. The results of this study supported this hypothesis. First, although there was a significant overall effect of clarity ($F=4.60$; $df=1,21$; $p<.05$), blurring the stimuli significantly increased localization errors for only the oldest age group. This was shown through a post-hoc analysis of the significant interaction between the variables clarity (blur versus no blur) and age ($F=4.09$; $df=2,21$; $p<.05$). Mean percent error rates for younger observers were .40 for blurred conditions and .42 for unblurred conditions, for middle aged observers .81 under blurred conditions and .78 under unblurred conditions, and for older observers 1.13 under blurred conditions and .99 under unblurred conditions. A Tukey test indicated that the differences between young and middle aged observers under blurred and unblurred conditions were nonsignificant, while the older observers performed significantly worse under blurred conditions ($p<.05$). Since blurring the images effectively lowers the spatial frequency content of the stimuli, it appears that the older observers had difficulties localizing the target stimulus when it's spatial frequency content was lowered. This result is consistent with the sustained/transient shift as discussed by Kline and Schieber (1981).

It was also hypothesized that the lower spatial frequency content of the unfilled faces distractor conditions would result in more localization errors among older subjects than younger subjects. This result was not observed. The distractor conditions did not seem to differentially affect the performance of older adults. However, there was a significant interaction between clarity, distractor condition (filled versus unfilled faces), and age ($F=4.65$; $df=2,21$; $p<.05$). The performance of young, middle, and older age groups under both clarity conditions is shown for both distractor conditions in Figure 2. Mean percent error rates for young observers under unblurred conditions were .52 and .316 for filled and unfilled distractor conditions, respectively. A Tukey test revealed this difference to be significant ($p<.05$). No other significant differences between filled and unfilled distractor faces were revealed, however, for either blurred or unblurred conditions. This indicates that young observers made significantly fewer localization errors when distracted by unfilled faces (unfilled symbols) than when they were distracted by filled faces (filled symbols) in the unblurred conditions.

For the older observers, no significant differences existed in the amount of localization errors for either distractor condition. This indicates that older observers may have more difficulty in processing low spatial frequency

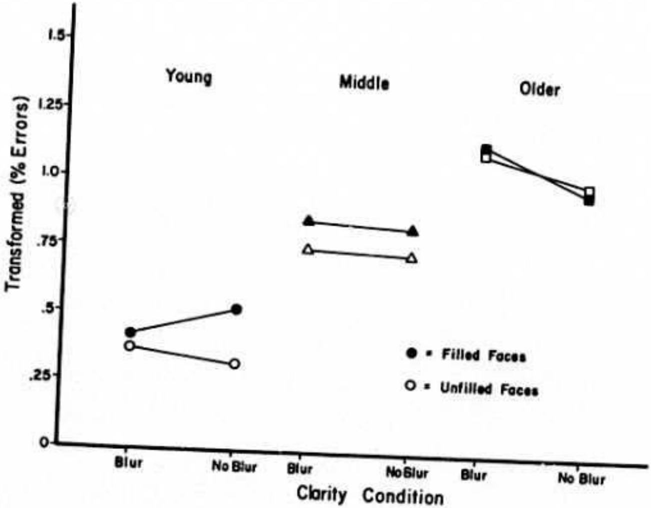

Figure 2. Error Rates Across Clarity Condition and Distractor Condition

information, since younger observers performed better when distracted by unfilled faces (less high spatial frequency information) than by filled faces. The older observers performed poorly with both types of distractor. Also note in Figure 2 that older adults made significantly more localization errors under blurred conditions regardless of distractor conditions, as indicated by a Tukey test ($p<.05$). Thus, it appears that older adults may have deficits in processing low spatial frequency information, which is consistent with the model of the aging human visual system proposed by Kline and Schieber (1981). These results also support the findings of Burbeck (1986) who found that the spatial frequency content of a peripheral localization target could effect localization accuracy of that target. These findings contradict those of Post and Leibowitz (1980), however, who found that blurring stimuli did not effect localization accuracy for those stimuli.

An alternative explanation for the results presented in Figure 2 is that among younger subjects the high spatial frequency content of the filled faces distractor condition inhibits mechanisms processing low spatial frequency information. This interaction may not have been observed in the older age groups because of the brief exposure durations employed. It is possible that given longer exposure durations, which would be more likely to tap the sustained system, older observers would exhibit similiar results. This type of sustained/transient interaction is consistent with the work of von Grunau (1978).

Directly related to the above hypothesis, it was also hypothesized that older adults process visual information at a slower rate than younger observers. The results of this study supported this hypothesis. In general, as exposure duration decreased, the number of localization errors made by observers increased ($F=56.20$; $df=3,63$; $p<.0001$). In addition, there was a significant interaction between age and exposure duration ($F=2.59$; $df=3,6$; $p<.05$). Results are presented graphically for each age group at all exposure durations in Figure 3. The circular symbols represent the performance of the young observers, the triangular symbols represent the middle aged observers, and the square symbols represent the performance of the older aged observers. Mean percent error rates for young subjects were .191, .305, .494 and .653 for presentation speeds of 150 msec, 125 msec, 100 msec and 75 msec, respectively. At a presentation speed of 100 msec, the mean percent error rate for older observers was 1.104 compared to .858 for middle age observers. A Tukey test revealed significant differences between the performance of young observers and the performance of middle and older age observers at all presentation speeds, with young observers making fewer localization errors at each presentation speed ($p<.05$). A Tukey test also indicated that older observers made significantly more localization errors than middle aged observers at a presentation speed of 100 msec ($p<.05$).

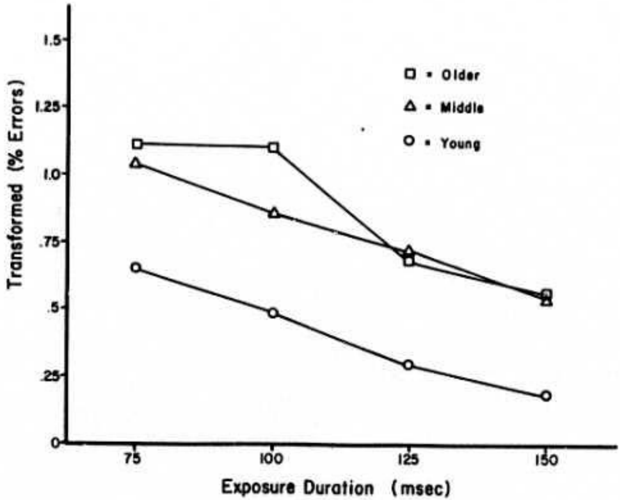

Figure 3. Error Rates Across Exposure Duration

Figures 4 and 5 illustrate the age x clarity x distractor condition interaction for exposure durations of 75 msec and 150 msec for young and older observers. Notice in Figure 4 that young observers made fewer localization errors when distracted by unfilled faces regardless of clarity condition for both exposure durations. This difference was greater at exposure durations of 75 msec than at exposure durations of 150 msec. In Figure 5, however, the older observers are shown to make fewer localization errors when distracted by filled faces under unblurred conditions at 75 msec. This relationship was reversed, however, for the blurred conditions. At 150 msec exposure durations distractor conditions had no effect on the number of localization errors made by older observers, indicating the effect of distractor condition and clarity on older observer's from Figure 2 was progressive with decreasing exposure duration.

These results were also consistent with the model of Kline and Schieber (1981) which states that the reduced inhibition of the "transient" channels on the "sustained" channels with age should increase processing time of visual information processing among older observers. However, neither the age x speed x distractor nor the age x speed x clarity interactions were significant. This is consistent with the interpretation that older adults experience a general slowing in their speed of processing and within the range of duration tested here only the transient system was

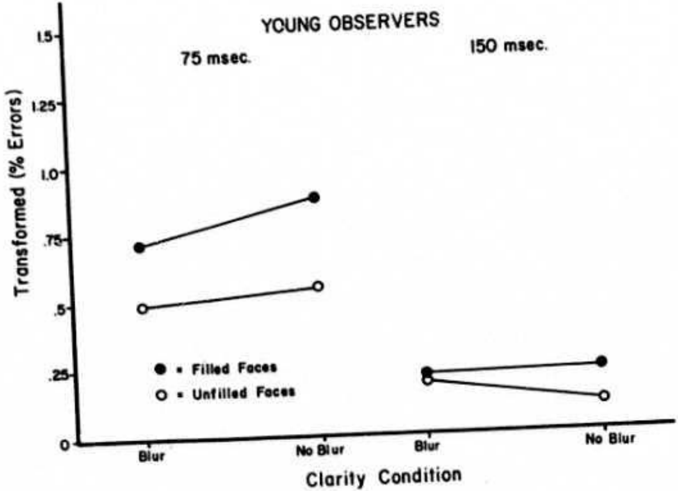

Figure 4. Error Rates Across Clarity Condition, Distractor Condition, and Exposure Duration (Young)

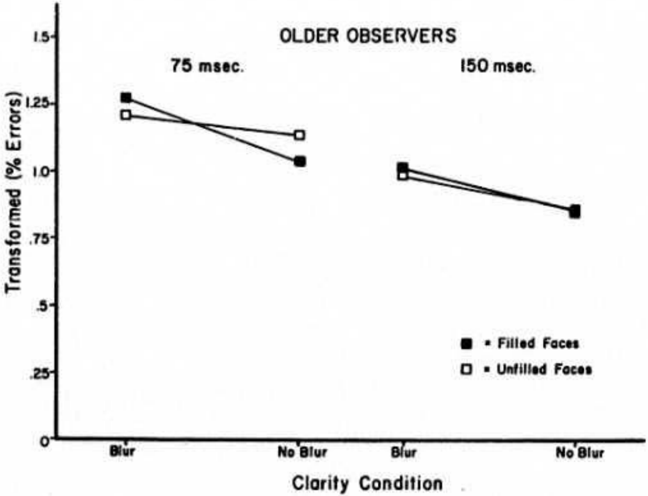

Figure 5. Error Rates Across Clarity Condition, Distractor Condition, and Exposure Duration (Old)

capable of responding.

Some indication of the degree of slowing in the older group can be gained by reexamining Figure 3. Notice the large gap in the amount of localization errors made by younger observers compared to the middle aged and older observers. This suggests that speed of processing begins to decline before observers reach the older ages tested in this study. Also notice that middle and older aged observers made roughly the same amount of localization errors at exposure durations of 75 msec and 125 msec, although they made significantly more localization errors at exposure durations of 75 msec as indicated by a Tukey test ($p<.05$). However, middle aged observers made significantly fewer localization errors at exposure durations of 100 msec. This pattern suggests that the critical exposure duration at which older adults can no longer accurately localize peripheral targets lies somewhere between 75 msec and 125 msec.

Finally, it was hypothesized that as target eccentricities increased localization errors would increase, and that this effect would be more pronounced for older observers. The results of this study supported this hypothesis. In general, as target eccentricities increased, localization errors increased ($F=47.82$; $df=2,42$; $p<.0001$). However, this effect was not more pronounced for the older observers, as indicated by the insignificance of the age x eccentricity interaction. There was, however, a significant interaction between clarity condition, target eccentricity, and age ($F=3.36$; $df=4,42$; $p<.05$).

The age x clarity interaction is broken down as a function of eccentricity in Figure 6. Both the young and middle aged observers performed equally well at eccentricities of 7.5 and 15 degrees (solid lines and dotted lines, respectively) regardless of clarity conditions. However, a Tukey test indicated that both groups made significantly more localization errors at test stimuli eccentricities of 22.5 degrees (square symbols) for both clarity conditions ($p<.05$). This pattern differed for the older observers. Under unblurred conditions the older observer's performance was consistent with the performance of the young and middle aged observers. However, under blurred conditions the older observer's performance was not consistent with the performance of the young and middle aged observers. There was not a significant difference in error rates under blurred conditions at eccentricities of 7.5 and 22.5 degrees, but a Tukey test revealed that older observers made fewer localization errors at 15 degrees eccentricity ($p<.05$). Error rates in general were higher for the older subjects under blurred conditions, indicating that under conditions of blur, target eccentricity did effect localization error rates for older adults more than younger adults. These results are consistent with previous results obtained by Ball (1985) and Sekuler and Ball (1986).

Conclusions

In conclusion, it appears that older adults do

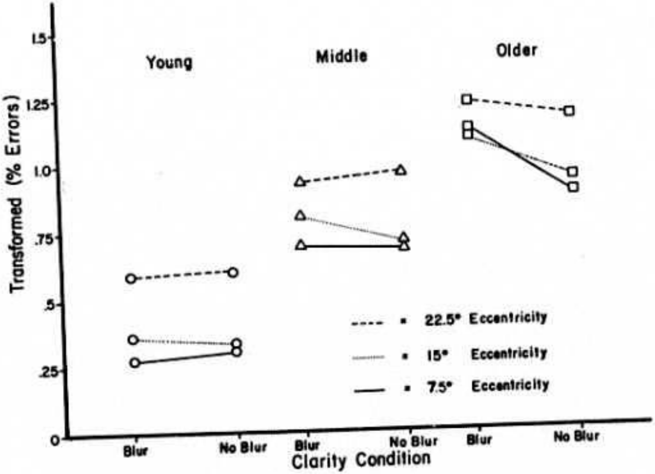

Figure 6. Error Rates Across Clarity Condition and Target Eccentricity

experience a progressive loss in their ability to process low spatial frequency information. Older adults also seem to have a slower speed of processing visual information. These results are consistent with the model of Kline and Schieber (1981), who proposed that older adults experience declines in transient visual information processing channels. However, in light of experimental evidence contradicting a distinct transient/sustained system dichotomy, care should be taken when viewing these deficits as strictly in "transient" mechanisms. These results should only be viewed as suggesting deficits in processing low spatial frequency information among older adults.

The present study may also help explain the results of Ball (1985), who found that older adults had more difficulty localizing peripherally presented faces than younger adults, and that box faces were harder to localize than oval faces for all observers. Perhaps a slower speed of processing among older adults can account for some of the older adults localization errors, in addition to the finding that older adults initially have difficulties separating relevant from irrelevant targets. Also, there may have been some difference in the spatial frequency content between the box and face targets that could account for the box target being more difficult to localize. Future research might examine older adults performance using box face and oval face targets presented at a wider variety of exposure durations and various levels of clarity compared to younger observers performance on the same tasks. Future studies should vary the spatial frequency content of the stimuli systematically to gain a more precise view of how older and younger adults process different spatial frequency information. Future research could also focus on more precisely determining at what age the observed slowing of visual processing begins to occur. Using observers of ages between the ages used in the young and middle aged groups in this experiment could more precisely locate the point where the slowing of visual processing begins to occur. Finally, by extending the range of exposure durations, future work could more accurately determine at what exposure durations older subjects begin to experience difficulties processing visual information. As mentioned previously, extending the range of exposure durations might reveal sustained channel inhibition of transient channels in the older age groups. Research such as this could elucidate the bases for declines experienced by older adults in the extent of the functional visual field.

Appendix A

Subject Information Sheet

SUBJECT INFORMATION

Name________________________ Date____________

Address______________________ Age____________

_______________________________ Phone____________

* *

Medical History

Medications____

Major illnesses_____________________________________

Visual history

cataracts_______ macular degeneration_______

diabetes_______ glaucoma_______

* *

Correction

Current distance bifocals Current near

Left_______ Left_______

Right_______ Right_______

Snellen acuity_______ Near acuity_______

Lab distance Lab near

Left_______ Left_______

Right_______ Right_______

Snellen acuity_______ Near acuity_______

Date of last eye examination_______ Optom_____ Ophthal_____

Name of Ophthalmologist______________________________

Visual complaints____________________________________

* *

Personal Information

Driving_______

Occupation__________________________

Other experiments____________________ Date_______

____________________ _______

____________________ _______

Other comments________________________________

____

Appendix B

Informed Consent Sheet

RESEARCH PROJECT: IMPROVEMENT OF VISUAL PROCESSING

Participant Consent Form

I, ______________________________, voluntarily consent to participate in a research study on how the aging process affects vision. The study will take place in the Vision Laboratory at Western Kentucky University, Bowling Green, Kentucky and will involve no more than 10 one hour sessions. The nature and purpose of the study have been explained to me. I understand that I will be asked to view a video monitor and indicate when I see certain patterns on the screen. These sessions use standard eye exam and exercise procedures that involve no risk to the participant. In the event of eye or position fatigue, I know that I can take rest periods when I feel the need and can ask questions at any time.

I understand I will receive compensation for my participation. In addition to any improvements to my visual functioning I may also (participants over 60 years of age) receive a free ophthalmological exam.

All results and eye examinations will be treated as confidential information.

Any questions about the research may be directed to Dr. Karlene Ball (phone 745-4438).

I further understand that I may discontinue participation at any time.

______________________________ ______________________________

Date Signature

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