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Anisms Underlying Improvement of Peripheral Visual Processing in Older Adults

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Mechanisms Underlying Improvement of Peripheral Visual Processing in Older Adults

A Thesis
Presented to the Faculty of the Department of Psychology
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment of the Requirements for the Degree Master of Arts

by
David A. Ball
July 1985
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Mechanisms Underlying Improvement
of Peripheral Visual Processing in Older Adults

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Dean of the Graduate College
Acknowledgements

I would like to take this opportunity to thank the members of my committee: Dr. Doris Redfield, Dr. John O'Connor, and Dr. Karlene Ball. Their comments, suggestions, encouragement, expertise and time were invaluable to me in completing this project. I would also like to thank David Griggs for all his help in working with the participants.
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Mechanisms Underlying Improvement
of Peripheral Visual Processing in Older Adults

David A. Ball

July, 1985

53 pages

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The aim of this project was to examine the effects of perceptual learning, or practice, on the vision of older adults. Previous findings had indicated that older adults have restricted functional visual fields, but that practice in detecting peripheral targets can substantially improve their performance. Two possible explanations for poorer performance in the older age groups were examined: 1) slowed speed of central perceptual processing and 2) attentional deficit problems. Six observers in each of three age groups were tested and trained in performing a peripheral localization task while performing a concurrent central task. A progressive loss in the functional visual field was again demonstrated as a result of age. All age groups, however, improved significantly in their performance of the task over seven sessions. Results supported the attentional deficit explanation for poorer performance in the older age groups. The findings were consistent with the position that older observers find it more difficult to avoid processing irrelevant information
in the visual field. Future research will need to
determine whether or not improved performance following
practice endures with time.
Chapter I

Introduction

Sensory psychologists have recently become interested in the practice effects observed while performing many visual tasks. As observers are required to detect the presence of, or discriminate between, various visual patterns, their abilities sometimes improve substantially. This "perceptual learning" may reflect an improved ability to pick out distinguishing features (Fiorentini & Berardi, 1981; Gibson, 1969), an improvement in describing the experience correctly (Brown & Lenneberg, 1954), or in better attentional skills (Keith et al., 1980). At other times improvement cannot easily be explained in any of these ways and practice seems to have an effect on the sensory system directly (Ball & Sekuler, 1979; Ball & Sekuler, 1982; Ball & Sekuler, 1985; Masland, 1969).

The aim of this project was to examine the effects of perceptual learning, or practice, on the vision of older adults. Previous psychophysical studies have indicated that older adults have impaired abilities on visual tasks which require the use of peripheral vision (Sekuler & Ball, submitted; Wolf, 1962; Wolf & Nadoski, 1971). In addition, studies have indicated that practice can improve the performance of both young and older adults on these
tasks (Ball & Sekuler, in preparation; Sekuler & Ball, submitted). Although there is a considerable body of literature which describes some of the visual problems of older adults, there remains little information concerning the basis for age-related losses, the underlying mechanisms for any improvement when practice is effective, or practical methods for treating visual problems. These issues were addressed in this project by determining how visual training might best be applied to just one of the problems experienced by older adults in their everyday environments.

Peripheral vision is typically mapped with a small dim light which probes the sensitivity of various retinal locations. The observer is instructed to fixate a clearly visible target and report when the small probe light is detected. Researchers using these techniques have reported some shrinkage of the visual field with age for both static and kinetic perimetry. These techniques, however, do not resemble the type of task an observer would encounter in everyday contexts. Other investigators have shown that visual field size may also shrink due to oxygen deprivation (Kobrick, 1972; Kobrick, 1974), alcohol ingestion (Moskowitz & Sharma, 1974), stress (Yasuna, 1946), secondary task requirements (Ikeda & Takeuchi, 1975; Leibowitz & Appelle, 1969; Williams, 1982) and the presence of peripheral noise (Mackworth, 1965). All of these studies tend to support the principle that
peripheral vision depends upon central as well as sensory processes. Standard perimetric techniques such as described above incorporate none of the above mentioned factors, and are probably not providing a realistic picture of the functional visual field in everyday environments. Everyday vision involves uncertainty, stress, secondary task requirements, and distractors at the very least.

Ball and Sekuler (in preparation) have designed a perimetric test which is more naturalistic than the kind typically used to assess visual fields. They found that although secondary task requirements, uncertainty, and visual noise had some small effect on the performance of young observers, these variables had very dramatic effects on the performance of older adults. Furthermore, practice on the task substantially expanded the functional visual field for the older observers under their conditions. Several questions remained following their study:

1. Why does the presence of distractors in the visual field affect older observers more than younger ones?

2. Would intermediate age groups be adversely affected by the presence of distractors?

3. What is the mechanism for improvement with training?

The present experiment sought to answer these questions by distinguishing between two possible
explanations for poorer performance in the older age
groups: 1) older adults are slower than younger adults in
the speed of central perceptual processing or 2) older
adults have an attentional problem which makes it more
difficult for them to ignore irrelevant or interfering
stimuli. In addition, the present experiment extended the
previous study (Ball and Sekuler, in preparation) by
involving three different age groups (young, middle-aged,
and older) to determine whether the onset of age related
losses is a gradual process.
Chapter II
Literature Review

Visual Field Studies

As stated earlier, peripheral vision is usually measured with a small dim light which probes the sensitivity of various retinal locations. The observer is instructed to fixate on a central visible target and report when the small probe light is detected in the periphery. These techniques, however, do not resemble the type of task an observer would encounter in everyday contexts and thus do not measure the "functional visual field" (the extent of peripheral vision that would be available under ordinary circumstances).

Several studies have shown that the functional field of vision shrinks as the demands of the task are increased, or distraction is present. For example, Gasson and Peters (1965) reported shrinkage of peripheral vision for light detection when observers had to concentrate on a velocity control test in foveal vision. Mackworth (1965) reported that visual noise (i.e. distraction) can go as far as causing tunnel vision. In addition, Bouma (1973)
also reported a reduction in the functional visual field due to noise in the background.

More recently, several investigators have combined the effects of several variables in examining the functional visual field. Williams (1982) reported that difficult visual-cognitive tasks resulted in a generalized shrinkage of the functional visual field. Ikeda and Takeuchi (1975) also found a shrinkage in this field with increased foveal demands plus the addition of a noisy background. In addition, these investigators found that the functional field could be enlarged with practice.

These findings replicated the findings of Engel (1971) who noted that the functional visual field enlarges during training. Engle hypothesized that possibly observers were learning to shift their attention to the periphery without sacrificing their performance on a concurrent foveal task.

Most recently, Ball and Sekuler (in preparation) sought to develop a more realistic perimetric test which incorporated uncertainty as to where a target might appear, as well as the presence of visual distractors and a concurrent foveal task. They hoped, thereby, to be able to estimate the size of the functional visual field which would be available under ordinary circumstances for different age groups. A description of their experiment and results follows, since the present experiment is an outgrowth of their study.
Fifteen young observers (mean age = 25) and nineteen older observers (mean age = 69) were tested. Stimuli were presented on a large monitor (60 x 60 degrees) for 125 milliseconds (msec). This brief presentation did not allow sufficient time for observers to initiate and complete a shift in fixation during the test interval. The test stimulus consisted of a cartoon likeness of a face subtending 1.5x3.0 degrees. The face appeared unpredictably, but equally often in each of 24 different peripheral locations: along eight meridia (the four cardinal meridia as well as four intermediate, oblique meridia), and at three different eccentricities from the center of the display: 5, 10, or 15 degrees.

In stimulus plus distractor conditions the single test face was accompanied by 47 outline boxes of the same size and luminance as the face itself. These distractors occupied all of the 23 remaining possible peripheral face positions as well as some intermediate positions. In addition, some conditions also required a concurrent central task. In one of these conditions (low demand) an additional cartoon face, the same size and shape as the one presented peripherally, was presented in the center of the fixation box. The observer was required to first identify the expression on the central face (smiling or frowning), and then identify the location of the peripheral face by pressing the appropriate key on a keypad. In another condition (high demand) two additional
faces appeared in the central box and the observer was required to identify whether these two faces had the same or different expressions before identifying the position of the peripheral target. There were thus six conditions: no central demand with and without distractors, low central demand with and without distractors, and high central demand with and without distractors.

After 125 msec the entire test display was replaced with a masking field to obliterate any residual afterimage. One second later a radial pattern appeared with eight equally spaced spokes labelled 1 to 8. This pattern remained until the observer made the localization response.

The primary interest was in the distribution of errors made in radial localization. Young and older observers made very few localization errors with the absence of a central task and no distractors (the condition most similar to typical perimetric measures). Errors increased for both groups with the addition of the central tasks and peripheral distractors, particularly as the eccentricity of the peripheral stimulus increased. However, the combination of central task and distractors affected older observers far more than it did younger observers. Although both the central task and the presence of distractors affected radial localization significantly, the distractors had a much greater overall effect. Furthermore, the central task affected both age groups
about equally, but the distractors affected older observers more than younger ones. Thus the age difference seemed to be primarily determined by the presence or absence of distractors in the visual field.

The increase in error rate, particularly at greater eccentricities, suggests a loss in the quality of peripheral vision. Additionally, the growing divergence between the two age groups confirms that this reduction in vision is more substantial for older than for younger observers.

Ball and Sekuler (in preparation) wondered what was causing the age difference. They tested twelve young observers while they viewed the display through various positive lenses (producing differing amounts of blur). These lenses sharply increased errors as to the expression of the central face, but had no effect on localization of the peripheral face. Therefore the difference between age groups could not be accounted for by the slightly poorer visual acuity of the older observers.

Since the older age groups exhibited functionally restricted visual fields in the distractor conditions, Ball and Sekuler (in preparation) recruited nine representative observers from their older group to determine whether practice would be of benefit. They had observers practice in four additional sessions, making 72 localization judgments in each session. Performance in all conditions improved significantly, with the most
improvement found for the most difficult conditions. Although the total practice did not entirely eliminate the age differences, older observers were able to reduce their field loss by more than 50%.

In conclusion, the visual field studies demonstrated an age-related difference with respect to the influence of distractors in the visual field. Training can be effective, for both older and younger observers, in expanding the usable peripheral vision. These studies, however, left unanswered the questions of why distraction is more of a problem for older observers, and the underlying mechanisms for improvement.

Two possible explanations for the effects of distraction on the performance of older observers will now be discussed: 1) Stimulus Persistence Theory, and 2) Selective Attention Theory. For each theory there is evidence that older individuals do not perform as well as younger observers, and that some of this age-related deficit can be removed through practice.

**Stimulus Persistence Theory**

According to this theory stimulus traces persist longer in the nervous systems of older people than they do in younger people (Botwinick, 1978). Evidence supporting this theory typically comes from masking studies in which the first stimulus (the target) is masked by a second stimulus (called the masking stimulus). If older people
experience the effects of the first stimulus for a longer period of time than younger people, then they ought to be more affected by the second masking stimulus than younger observers. This has been shown to be true in several studies. For example, Kline and Szafran (1974) and Kline and Birren (1975) found that older people were more susceptible to a masking stimulus than younger people, indicating that it takes older people longer to process a stimulus than younger people.

Walsh (1976), Walsh, Till and Williams (1978), and Walsh, Williams and Hertzog (1978) also performed masking studies which supported stimulus persistence theory. They reported that older people have a slower speed of perceptual processing. Stimulus persistence, however, was also found to be modifiable with training. Hertzog, Williams, and Walsh (1976) found that both young and old observers were able to reduce processing time with training. Their observers practiced detecting the test stimulus, followed by a masking stimulus for five days. The effects of practice were equivalent for the two groups. They reported that age differences in speed of central processing remain stable over 5 days of practice, even though both age groups show large decreases in processing speed. Walsh (1976) reported that old adults (over 60 years of age) were 24% slower than young adults in the speed of central perceptual processing. Even with practice this 24% difference was found to be constant.
This notion of slower perceptual processing among older persons might account for the results of Sekuler and Ball (submitted, 1985). Since observers were only permitted to view the test stimulus for 125 msec, and the stimulus was then obliterated by a masking stimulus, it could be the case that older observers had not processed the stimulus to the same extent as the younger observers. If older observers did not have enough processing time to escape the effects of the mask then they would be expected to exhibit poorer performance on the task. Since others have reported that the speed of central perceptual processing can be increased with practice, this may be the mechanism underlying improvement of observers on the functional visual field task as well.

**Attentional Deficit Theory**

Another theory which has been used to account for age-related declines in performance is that of an attentional deficit. Investigators have wondered whether older observers have a deficit in selective attention which leads to the processing of irrelevant information. For example Rabbitt (1965; 1979) found that as the amount of irrelevant letters on a card increased from 0 to 8 that the magnitude of age differences in sorting time also increased. He interpreted this to mean that the elderly have difficulty ignoring irrelevant information.

Similarly, Layton (1975) reported that the elderly have
difficulty ignoring "perceptual noise" which he
categorized as irrelevant or interfering stimuli.

Shiffrin and Schneider (1977) have drawn a
distinction between divided attention, and focused
attention. In divided attention observers must monitor
additional sensory input or memory items for the presence
of relevant information. In this case there are many
inputs, any of which could potentially contain the
relevant information. In focused attention, however, the
observer knows only certain inputs are relevant, but
cannot avoid processing irrelevant inputs. Farkas and
Hoyer (1980) found that if distractors differ in
orientation from the target, and observers know the
target's location, then the presence of irrelevant stimuli
does not increase target discrimination time in either old
or young observers. They concluded that age deficits may
only occur when a visual search is required and that older
observers may only be unable to ignore irrelevant
information when they do not know the target's location.

Consistent with the above studies was Nebes and
Madden's (1983) findings that when stimulus relevance can
be determined from some salient physical feature (color or
location) that the old can focus their attention as well
as the young. Plude et al (1983) similarly report that a
selective attention deficit occurs when processing
resources are overloaded and that age decrements are
observed when the elderly must select among simultaneous inputs (i.e. a divided attention type of task).

Evidence for improvements in divided attention tasks with practice are substantial (Wickens, 1984). In Ball and Sekuler's study divided attention was clearly required since observers did not know the location of the relevant target and observers were forced to select among simultaneous inputs. If, during practice, observers are learning to ignore the irrelevant stimuli while focussing on the relevant target, then the age difference found initially could be due to the nature of the divided attention type of task. If, in fact, this is the case, then switching the relevant target with the irrelevant one following training ought to reverse the effects of training and produce substantial differences between the young and older groups once again.
Chapter III
Method

Observers
Six observers were tested in each of three age groups. The performance of young adults was compared to that of middle aged and older adults. The young adults tested were in the age range from 19-29 years; middle aged adults ranged from 43-51 years; older adults ranged in age from 61-75 years. These age groups allowed an evaluation of developmental trends throughout adult life.

Since the focus of the research was on changes in vision as a function of the normal aging process, it was extremely important that all observers be free from ocular pathology. Several eye diseases with associated vision loss occur more frequently in later adulthood (Leibowitz, et al., 1980) (e.g. macular degeneration, glaucoma, cataract). While it is often difficult to separate the biological changes simply due to age from those due to disease (Ludwig, 1980), there are a great number of older adults who exhibit no ocular pathology, but who do report visual problems. It was these individuals who were of primary concern in this experiment.

The following procedure was used to obtain information about the eye health of all observers:
a. When a person expressed interest in participating in the research, the nature and purpose of the study were described. It was specifically mentioned that the research concerned visual changes in later life and that only those individuals with no history of eye disease would be tested. A screening interview was then conducted in which the individual was asked whether an eye-care specialist had ever indicated the presence of any type of disease (other than refractive error). Potential observers were specifically questioned about macular diseases, glaucoma, cataracts, optic neuritis and diabetic retinopathy. Potential observers were also asked if they had a history of diabetes or neurological problems. If a potential observer reported that they had any of these problems it was again explained that because of the nature of the research it would be impossible for them to participate, and they were thanked for their interest. A copy of the Subject Information Sheet, on which these answers were recorded, is included in Appendix A.

b. If the potential observer reported no history of eye disease and was still interested in participating, he/she was asked to read and sign an informed consent form (see Appendix B). The observer was then informed of how many sessions would be required and seven appointments were scheduled.

c. As one final measure of eye health each observer was refracted for the experimental viewing distance. This
was done to ensure that all observers had normal acuity for their age, and to ensure the elimination of blur at that viewing distance. Acuity measurements for distance (3 meters or farther) were obtained with a Bailey-Lovie Distance Chart. Acuity measures for near distances (under 1 meter) were obtained using the Bailey-Lovie Near Charts. If corrective lenses were needed for best corrected acuity they were worn during the experimental sessions. Refraction is extremely important because optical blur significantly affects the visibility of smaller targets (Ogle, 1961). In addition, the test distance in the present study was relatively short, making it difficult for older, presbyopic, observers to focus on the display.

Because of the optical differences between old and young eyes, the older retina receives less light than the younger retina. Reduced retinal illuminance in older eyes is primarily the result of (1) senile miosis, the reduction of pupil size with age and (2) increased optical density of the crystalline lens (Weale, 1963). Weale has estimated that the 20 year old eye transmits three times more light to the retina than the 60 year old eye. Reduced retinal illuminance can lower an observer's sensitivity to smaller targets. Since the focus of this research was on age-related effects in performance other than those attributed to retinal illuminance, stimuli were presented at a contrast far above threshold for any age group in order to equalize stimulus conditions across age.
As differences between young and older observers are found, it is important to know whether the differences are due to sensitivity differences or reflect the use of different criterion by young and older observers. Several studies on decision processes in the elderly report that they tend to be more "cautious" (Botwinick, 1978). In particular, when older observers are confronted with situations in which they are not sure what stimulus was presented, they will be more likely to state that they saw nothing, or will refuse to respond altogether. Many times, although older adults do have some information about a stimulus, their reticence to guess or respond makes them appear to have more of a sensory deficit than they actually have. To allow interpretation of age differences, criterion free measures of sensitivity or discriminability were obtained by using a forced choice procedure. In this procedure observers are required to make a response following each presentation, and thus spurious differences due to differing criteria can be eliminated.

**Stimuli**

The test stimuli were similar to those described by Sekuler and Ball (submitted). In one condition, a cartoon likeness of an oval human face subtending 1.5 x 3 degrees served as the peripheral target. This face appeared unpredictably, but equally often, in each of 24 different
positions in the display: along eight meridia (the four cardinal meridia as well as the four intermediate, oblique meridia), and at any of three different eccentricities (5, 10 or 15 degrees). In the other condition, a box face (which is a square shape with eyes and a mouth inside) of approximately the same size and luminance as the oval face, served as the relevant peripheral target. Stimuli were presented on a large video screen (60 x 60 degrees) under computer control.

Distractor stimuli were either outline boxes with no internal detail when the oval face was the relevant peripheral target, or outline oval faces with no internal detail when the box face stimulus was the relevant peripheral target. The concurrent central task consisted of an additional face (identical to the relevant peripheral target) which appeared in the center of the fixation box. This face varied in expression (either smiling or frowning), producing the two expressions equally often but in a random order.

**Procedure**

Observers were seated with their heads positioned in a chin rest 57 centimeters (cm) from the display. Their eyes were level with the center of the screen and viewing was binocular. At this viewing distance 1 cm on the screen represented 1 degree of visual angle. The task was demonstrated for each observer and he/she was given the
opportunity to ask questions and familiarize him/herself with the task prior to beginning the experiment.

Each trial consisted of four successive computer-controlled displays. The first display, a bright outline box (4 x 5 degrees) directed the observer's fixation to the center of the screen. After one second, the fixation guide was joined by the test stimulus for either 120 or 90 msec. Following this the entire display was replaced by spatially random masking noise to obliterate any residual afterimages on the display. Finally, one second later, a radial pattern appeared with eight equally spaced spokes, each labeled with a digit from 1 to 8. This spoke pattern remained visible until the observer made a radial localization response by selecting one of the eight numbers on a keypad located in front of him/her.

The observer made two responses at the end of each trial. The observer was instructed to first identify the expression on the central face by selecting one of two buttons on the keypad, and then to select the radial location of the peripheral face. Computer generated tones provided the observer with immediate feedback about response correctness. If a central response was incorrect then the trial was terminated with no additional responses being permitted. The terminated trial was then re-presented some time later in the block of trials. Observers received $6.00 per hour for their participation.
to enhance their motivation while performing the task.

The following distractor conditions were conducted.
In one condition the oval peripheral face, as the target, was accompanied by 47 outline boxes of the same size and luminance as the target face itself. These distractors occupied all possible face positions as well as positions between the eight meridia. In the other condition the relevant target was the box face and the distractors consisted of 47 outline oval faces in all possible target positions and the positions inbetween.

Trials were grouped in sets of 24, one trial with the peripheral face at each of its 24 possible positions. The order of testing with the two stimulus conditions was randomized for each observer. In the first session, observers were tested twice on each stimulus condition: once with a stimulus duration of 120 msec, and once with a stimulus duration of 90 msec. Thus in the first session each of the two distractor conditions was tested with two stimulus durations for a total of four blocks of trials. This enabled a comparison between conditions and speeds of presentation prior to training.

In the training phase observers were given practice on only one of the two conditions at the longer presentation of 120 msec. Half of the observers in each age group were randomly assigned to each of the training conditions (either box faces relevant or oval faces relevant). Each observer practiced on his/her assigned
condition for approximately 1/2 hour per day for five sessions. Following the five training sessions each observer repeated the procedure of the first session (i.e. was tested at both presentation speeds for both conditions). This allowed for a comparison of the same four kinds of trials following training and provided an opportunity to see whether improved performance on the training condition transferred to the other condition, and/or to the other presentation rate.

Several hypotheses will be examined following data collection. First of all, it is expected that there will be significant main effects of age, day of test (day 1 versus day 7), and of eccentricity. These results would be consistent with previous results obtained by Ball and Sekuler (in preparation). Secondly, significant interactions are predicted for condition x day, and speed x day if the improvements obtained through practice are restricted to the trained condition. That is, if the attentional deficit theory is correct, the improved performance obtained on the trained stimulus condition will not generalize to the untrained condition. If, however, the stimulus persistence theory is correct, these interactions would not be significant, and equal improvements would be predicted for both the trained and the untrained stimulus conditions.
Chapter IV

Results

The primary interest was in the distribution of errors made in radial localization. Errors were summed across the eight meridia and converted to percentages. Because the data were proportions (percent errors), for statistical and graphical analysis data were transformed by taking the inverse sine of the square root of the percent errors. On this scale, 1.2 corresponds to chance performance (84% errors), .79 corresponds to 50% errors, and 0.0 corresponds to 0% errors.

Data were analyzed using a repeated measures ANOVA. Age was the sole between groups variable with condition (trained versus untrained), speed (120 msec versus 90 msec), day of test (day 1 versus day 7) and eccentricity (5, 10 and 15 degrees) all repeated measures. The design was thus a 2 x 2 x 2 x 3 repeated measures for each of the three age groups. A diagram of this design is illustrated in Figure 1.

The results for the main effects will be summarized first. The ANOVA indicated a significant main effect of age (F=16.17; df=2,15; p<.001). Overall mean percent errors for the three age groups were .600, .855 and 1.065 respectively. A nonsignificant main effect was obtained
Figure 1. Schematic diagram of the experimental design.
for conditions \((F=1.02; \text{df}=1,15; p>.25)\). Mean percent errors for the trained condition collapsed across days was .783, with .897 percent errors for the untrained condition. A nonsignificant main effect was also obtained for speed of presentation \((F=1.50; \text{df}=1,15; p>.20)\). Mean error rate for the presentation speed of 120 msec was .827 overall, and .853 overall for the speed of 90 msec. There was a significant main effect of practice \((F=23.58; \text{df}=1,15; p<.001)\). Mean percent errors overall on day 1 was .956 with a reduction to .724 by day 7. Finally, the main effect of eccentricity was significant overall \((F=36.54; \text{df}=2,30; p<.0001)\). Mean percent errors at 5 degrees eccentricity was .742, with .804 percent errors at 10 degrees, and .975 percent errors at 15 degrees.

The results for the interactions will now be summarized. First of all, there was a nonsignificant interaction between the variables age and day of test \((F=.44; \text{df}=2,15; p>.5)\). This indicates that the significant age difference noted previously in the main effects remains constant across the two days of test. In other words, each age group was improving at the same rate.

There was a significant interaction between conditions and day of test \((F=18.83; \text{df}=1,15; p<.001)\). The mean percent errors on day 1 for the trained condition was .971, corresponding to .940 for the untrained condition. However, on day 7 the error rate was .595 percent errors for the trained condition corresponding to .853 for the
untrained. A Newman Keuls test revealed that the difference between the trained and the untrained condition, while nonsignificant before training, was significant following training (p<.05). In other words, the effects of practice were more dramatic for the trained condition than the untrained condition.

There was also a significant interaction between speed and day of test (F=5.25; df=1,15; p<.05). Mean error rate for 120 msec on day 1 was .971, corresponding to .683 on day 7. Mean error rate for 90 msec presentations was .941 on day 1 corresponding to .766 on day 7. A Newman Keuls test again showed that there was a significant difference between the 120 msec presentation rate on day 1 and the 120 msec presentation rate on day 7. The 90 msec presentation rate, however, did not improve significantly between day 1 and day 7.

All interactions with eccentricity were nonsignificant indicating that the effects of training, speed, and condition were uniform across eccentricities. Finally, there was a significant interaction between condition, speed, days, and age (F=4.09; df=2,15; p<.05). This interaction will be discussed and presented graphically in the next section. All of the results of the analysis of variance are presented in Table 1.
Table 1
ANOVA Summary Table

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Chapter V
Discussion

Results are presented graphically for the first and last test sessions in Figure 2. The filled symbols represent performance on the trained condition, and the open symbols represent performance on the untrained condition. Young observers are designated with circles, the middle age group with squares, and the oldest age group with triangles.

The lefthand portion of Figure 2 illustrates performance on the trained and untrained conditions at the longer presentation speed of 120 msec. Day of test is plotted on the abscissa with transformed percent errors shown on the ordinate. Note that the relationship between error rate and age remains constant across days with the youngest group making the fewest errors, the middle age group the next fewest errors, and the oldest age group the most errors overall. Next examine the effect of day of test for the trained condition (filled symbols). The youngest age group dropped from a mean error rate of .722 on day 1 to .262 on day 7. This represents a drop in error rate of .46. In comparison, the middle age group dropped from a mean error rate of 1.064 on day 1 to .590 on day 7 which represents a change of .45. Finally, the oldest age
Figure 2. Performance of all age groups summarized across day of test.
group dropped from a mean error rate of 1.280 to .848 on day 7 representing a change of .432. A Newman Keuls test revealed that on the trained condition, each age group improved significantly between day 1 and day 7 (p<.05).

The performance on the untrained condition at the same presentation speed of 120 msec is illustrated with open symbols. For this condition the youngest age group dropped from a mean error rate of .816 to .559 following practice (a change of .257). The middle age group went from a mean error rate of .812 to .871 (an increase by .059). Finally, the oldest age group dropped from a mean of 1.13 to .967 (a change of .163). For this untrained condition, the Newman Keuls analysis revealed a significant decrease in error rate between day 1 and day 7 for the youngest age group (p< .05). Significant differences were not obtained between day 1 and day 7 for the middle and the oldest age group. This is evidence for improvement for the untrained condition only for the youngest age group.

The righthand portion of Figure 2 illustrates performance on the trained and untrained condition at the faster presentation speed of 90 msec. For the trained condition (filled symbols) the mean error rate of the youngest age group went from .697 on day 1 to .390 on day 7 (a reduction by .307). The middle age group dropped from a mean error rate of .875 to .657 (a reduction by .217). Finally, the oldest age group dropped from a mean error
rate of 1.187 to .825 (a reduction of .362). These results appear to be more similar to those of the training condition at the slower presentation speed of 120 msec. In this case all age groups again show significant improvement between day 1 and day 7 (p<.05).

Performance on the untrained condition at the 90 msec speed is illustrated with the open symbols. In this case the mean error rate for the youngest age group dropped from .714 to .640 (a change of .074). For the middle age group mean errors dropped from 1.009 on day 1 to .961 on day 7 (a change of .048). The oldest age group dropped from a mean error rate of 1.16 to 1.12 (a change of .039). Under these conditions none of the age groups showed a significant difference between day 1 and day 7.

Several conclusions can be drawn from this figure. First, improvement on the trained condition was substantial, and equal, for all three age groups. Second, transfer of learning from the trained to the untrained condition only occurred for the youngest age group. In this age group improvement on the untrained condition was, however, significantly less than it was for the trained condition (p<.05). Third, transfer of training from the trained condition at the practiced presentation speed of 120 msec, to the trained condition at the unpracticed presentation speed of 90 msec was again significant for all age groups. Although improvement was less than for the practiced presentation speed, there was a consistent
improvement across age groups. Fourth, transfer of training to the untrained faster presentation condition did not occur.

The significant interaction between condition, speed, day of test, and age is clarified by these conclusions. The difference between day 1 and day 7 is significant for all age groups for both the trained condition at 120 msec and the trained condition at 90 msec. The difference between day 1 and day 7 is nonsignificant for all three age groups on the untrained condition at the 90 msec duration. However, there is a significant difference between days for the youngest group alone on the untrained condition presented at 120 msec.

Figures 3, 4, and 5 portray performance across all seven sessions for the trained condition and presentation speed. In Figure 3 performance for the young observers is shown separately for those trained on the box face targets and those trained on the oval face targets. Note first of all that the box face targets were consistently more difficult to detect than the oval face targets. Mean error rate for the box face targets was .60 overall on day 1, and dropped to .18 overall on day 7. In contrast, mean error rate on the oval face targets went from .28 on the first day to .03 on the seventh day. Thus performance on the oval faces was much better to begin with and errors were virtually eliminated across the seven sessions. Performance on the box face targets also improved with
Figure 3. Performance of the youngest age group summarized across training sessions.
Figure 4. Performance of the middle age group summarized across training sessions.
Figure 5. Performance of the oldest age group summarized across training sessions.
practice, although for these targets errors were still present following seven sessions.

Figure 4 illustrates the same effects for the middle age group. For this age group the mean error rate for the box face targets began at .92 on day 1 and dropped to .455 by day 7. Mean error rate for the oval face targets dropped, in contrast, from .58 overall to a mean of .19 on day 7. The discrepancy between box face targets and oval face targets was therefore even more pronounced for the middle age group, although there was significant improvement for both types of stimuli.

Finally, Figure 5 portrays performance of the oldest age group across seven sessions. For this age group the mean error rate for the box face targets was .92 on day 1, and dropped to .55 on day 7. Their performance was thus comparable to that of the middle age group on these targets. Performance on the oval face targets dropped from a mean of .86 on day 1 to .53 on day 7. This was somewhat surprising, in that for the oldest age group it did not appear to matter whether they were trained on the box faces or the oval faces. These two stimuli were equally difficult for this older group, while the oval faces were much easier for the younger and middle age groups.

One question related to the two types of stimulus conditions is whether training transfers differentially to the untrained condition. In other words, does improvement on oval face targets transfer more to box face targets
than improvement on box face targets to oval face targets. For young observers trained on oval face targets performance on the box face targets went from a mean error rate of .79 on day 1 to .46 on day 7. For young observers trained on box face targets performance on the oval face targets went from a mean error rate of .28 to .18. Thus for young observers, training on either condition appears to transfer to the other stimulus condition, although the overall error rate at the end of training is still higher than for the trained condition itself.

For the members of the middle age group trained on the oval face targets, performance on the box face targets went from a mean of .76 on day 1 to .81 on day 7. For those trained on the box face targets performance stayed constant at a mean error rate of .32 for both day 1 and day 7. Thus for the middle age group there appears to be no transfer from one stimulus condition to the other.

Finally, for the members of the oldest age group trained on the oval face targets, performance on the box face targets went from a mean of .81 to .83. For those trained on the box face targets performance dropped from a mean of .76 to .47 on the oval face targets. Thus for the oldest age group training on the box faces transferred to better performance on oval faces, but training on the oval faces did not transfer to improved performance on the box faces.
In conclusion, it appears that transfer of training from one stimulus to the other is most consistent with the performance of the youngest age group. For the two older age groups, it appears that improved performance on the box face targets is more likely to transfer to improved performance on the oval face targets than the other way around. In this case, training on the more difficult of the two tasks may be more likely to transfer to the easier task than vice versa.

The findings of this experiment replicate those of Ball & Sekuler (submitted, 1985) in that performance was affected by the age of the observer, and the functional visual field was expanded following practice. The performance of the middle age group in this study fell in between that of the youngest and oldest age groups indicating that the loss in the functional visual field is a gradual rather than a sudden occurrence.

The introduction to this experiment posed the question "why is there poorer performance in the older age groups?" Two hypotheses related to this questions were that 1) older adults are slower than younger adults in the speed of central perceptual processing, and 2) that older adults have an attentional problem which makes it more difficult for them to ignore irrelevant or interfering stimuli.

According to the stimulus persistence theory, stimulus traces persist longer in the nervous systems of
older people than they do in younger people. This could explain the difficulty that older observers have in performing this task, since observers were only permitted to view the stimulus for very brief periods of time. If training on the task only increases the speed of central perceptual processing in a general way, then one would expect transfer of improved processing to untrained stimuli. The data indicate that there is significant transfer to the untrained stimuli only in the youngest age group. Therefore results cannot be explained solely on the basis of a general increase in the speed of central perceptual processing.

According to the attentional deficit theory age-related declines in performance may be explained due to the fact that older observers cannot avoid processing irrelevant inputs. Improved performance following training might then be explained as the observers are learning which targets are relevant and which are not. They are thus learning, with practice, to ignore the irrelevant distracting stimuli in the display. Hence, this theory predicted that making the relevant target during training irrelevant following training would produce substantial problems for the older age groups. The data seem to be consistent with this theory in that older and middle aged observers show no transfer from the trained to the untrained stimulus conditions, while the younger observers do.
Finally, the fact that all observers showed improved performance on the trained condition at a faster presentation speed deserves some comment. Recall that improvement at the 90 msec duration was specific to the training condition; this finding does not necessarily support the stimulus persistence theory. Rather, a more plausible explanation might be that as observers become more proficient at separating the relevant from the irrelevant targets in the display, they are able to do so in less time. Thus an improved ability to make the discrimination between relevant and irrelevant targets may also show up in faster processing times. The more familiar the target, the less time it would take to process the display.

Conclusions

In conclusion, it appears that there is a progressive loss in the functional visual field with age. This loss, however, can be largely reversed through practice over a relatively brief time. Transfer of training from a trained stimulus configuration to an untrained condition, where the relevant and irrelevant stimuli are reversed, appears to be possible only for the youngest age group. These findings are consistent with the position that the older observers find it more difficult to avoid processing irrelevant information in the visual field. Finally, the finding that improvements on the trained condition
transfer to better performance at faster presentation rates of the same stimulus configuration indicates that as observers become more proficient at localizing the relevant target they can do so in less time.

Future research will need to examine whether or not improved performance following practice endures with time. In addition, the nature of the stimulus appears to be an important consideration. Why, for example, are box face targets more difficult to localize than oval face targets? What is the relationship between the characteristics of the central target and the peripheral target? Could the visual field be expanded beyond the 15 degrees tested in this study? These questions need to be addressed in order to more fully understand the conditions under which the functional visual field may be expanded.
Appendix A

Subject Information Sheet
## SUBJECT INFORMATION

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- **Major illnesses:**

### Visual History

- **Cataracts:**
- **Macular Degeneration:**
- **Glaucoma:**
- **Diabetes:**

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- **Date of Last Eye Examination:**
- **Optometrist:**
- **Ophthalmologist:**
- **Name of Ophthalmologist:**

### Visual Complaints

### Personal Information

- **Driving:**
- **Occupation:**
- **Other Experiments:**

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Appendix B

Informed Consent Sheet
I, ______________________, voluntarily consent to participate in a study on how the aging process affects vision. The study will take place in the Vision Laboratory at Western Kentucky University, Bowling Green, Kentucky. The nature and purpose of the study have been explained to me. I understand that I will be asked to indicate when I see patterns on a screen. If I have not already seen the project ophthalmologist, I will be scheduled for a visit in the near future.

I know that I can take rest periods when I feel I need them and can ask questions at any time.

__________________________  ________________________
Date                        Signature
References


