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Attentional and Perceptual Contributions to the Identification of Extrafoveal Stimuli: Adult Age Comparisons

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Gerontological researchers have been cautioned that conclusions about age differences in attention may have been inferred from data that, in fact, reflected age differences in perceptual processing of stimuli falling outside the fovea (Cerella, 1985). Presumably, the experimental manipulations on which Cerella based his caution induced a broad focus of attention so that changes in perceptual processing would not be confounded with changes in attention. Experiment 1 tested this by comparing a condition similar to Cerella's with another in which attention was narrowly focused at fixation. The results replicated Cerella's findings. In addition, there were greater age differences when attention had been narrowly focused, showing that attentional effects can be separated from the effects reported by Cerella. Experiment 2 showed that age differences in extrafoveal perception could be removed by increasing the duration of the target from 200 to 2000 ms, suggesting that the perceptual deficits in older adults are due to differentially lengthened processing of stimuli outside the fovea.

REACTION times to a stimulus increase as the stimulus is presented farther from the fovea. The increase is greater in older adults than in younger adults. This has been found both for the identification of shapes (Cerella, 1985; Scialfa, Kline, & Lyman, 1987) and for localization (Scialfa & Kline, 1988; Sekuler & Ball, 1986). The age differences occur even when optical techniques are used to equate acuity across individuals (Scialfa et al., 1987; Sekuler & Ball, 1986). The characteristic result is a monotonic increase in reaction times as the target is farther from fixation (Cerella, 1985; Scialfa et al., 1987) and is also seen as an increase in errors (Scialfa et al., 1987; Sekuler & Ball, 1986).

LaBerge (1983; see also LaBerge & Brown, 1986) has also found a monotonic increase in reaction time to probes presented at increasing eccentricities from the focus of attention. For example, in a Letter-in-Word condition (LaBerge, 1983, Experiment 2), a five-letter word appeared as the first target. The first target was replaced by a second target, a 7, Z, or T presented at one of the five locations where a letter had been in the first target. The task was to respond if the center (third) letter of the first target was in the set A through G and the second target was a 7; a response was to be withheld otherwise. Reaction times increased with increasing distance of the second target from the location of the center letter, where attention was presumably focused.

Cerella (1985) has argued that conclusions about attention or attentional capacity could be drawn erroneously from data that reflect only the loss of sensitivity with increasing retinal eccentricity. That argument could be applied to LaBerge's (1983) finding. LaBerge, however, also included a Word focus condition in which the first target was again a five-letter word but the subject was to determine whether it was or was not a common first name. LaBerge reasoned that attending to the whole word should broaden the attentional focus beyond the narrow focus required to identify a single letter within a word. Consistent with this reasoning, the reaction times in the Word condition were unaffected by the eccentricity of the location of the second target. The reaction time function was flat.

For a strong conclusion that age differences are not due to attention, it would be desirable to use a procedure that induced a wide focus of attention. Cerella (1985) used either a row of dots or a row of sevens as the stimulus preceding the target. A reasonable strategy for the participants would have been to adopt a broad focus of attention, anticipating the full range of target locations. The two experiments reported here attempted to verify that Cerella's procedure induced a broad focus of attention by comparing a condition similar to his with another, similar to that used by LaBerge (1983), in which attention was focused on a single character.

In order to develop the predictions for the present experiments, the methods will be briefly previewed. The events on each trial in each condition of the experiments are listed in Table 1. On each trial, a warning/fixation stimulus was followed by two targets. In the unfocused conditions, designed to be similar to the procedure used by Cerella (1985, Experiment 1), the first target was a uniform string of Ss or 8s. In the focused conditions, designed to be similar to the procedure used by LaBerge (1983) and LaBerge and Brown (1986), the first target was a string of alternating 8s and 5s with either an S or an 8 in the center position. In all conditions, the second target was a 7 or Z flanked by brackets. With reference to the first target, the 7 or Z in the second target could appear at fixation or three or six character spaces to the left or right of fixation. The task was to respond if the first target contained an S and the second target contained a 7.

In the focused conditions, attention should be tightly concentrated on the center character of the first target, in order to identify it in the context of featurally similar sur-

Table 1. Events on Each Trial

Warning		# # # # # # # # * # # # # # # # #
First target		
Focused condition		8 5 8 5 8 5 8 5 S 5 8 5 8 5 8 5 8
	or	8 5 8 5 8 5 8 5 8 5 8 5 8 5 8 5 8
Unfocused condition		S S S S S S S S S S S S S S S S S
	or	8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
Second target		] 7 [or] Z [
Second target locations[a]		^ ^ ^ ^ ^

[a]Arrows show the location of the center character in the second target.

rounding characters. If the second target appears at the point of fixation, the response should be rapid. If the second target appears away from fixation, some adjustment of the attentional focus should be required, lengthening the response time. In the unfocused conditions, no tight focus of attention is required, as in LaBerge's (1983) Word condition. If observers can spread the attentional focus to encompass the entire range of the first target (and, therefore, of the second target), any effects of the eccentricity of the second target should reflect only perceptual effects. The attentional focus would not need to be adjusted.

It was predicted that the results in the unfocused condition would replicate those obtained by Cerella (1985). Reaction times should increase with increasing eccentricity of the second display, and they should do so more rapidly for older adults than for younger adults. The results in the focused condition should replicate those of LaBerge (1983), with reaction times increasing more rapidly with increasing eccentricity than in the unfocused condition. If the unfocused conditions induce a broader focus of attention, then the increase in reaction time with eccentricity should be less in the unfocused conditions than in the focused conditions. If older adults have an impaired ability to process peripheral targets, as Cerella has argued, and if that impairment is independent of the manipulation of attention, then the age differences should be the same in the focused and unfocused conditions. If, however, age differences are both perceptual and attentional, then the difference between the focused and unfocused conditions should interact with age.

Experiment 1

Method

Participants. — Twenty-four younger adults and 17 older adults participated in the experiment. The younger adults were college students (15 women, 9 men) participating for extra credit in social science courses. Their average age was 20.6 years (range, 18–24). On a 10-point scale with 10 as excellent health, the average self-rated health was 9.25. The older adults were community volunteers (14 women, 3 men) who transported themselves to the laboratory. Their average age was 70.8 years (range, 64–82), and their average health rating was 8.20. The two groups did not differ in self-rated health, $t(37) = .86$. Measured acuity, with corrective lenses if those were normally worn for reading, was 20/25 or better for all participants. The modal younger adult was 20/20; the modal older adult was 20/25. Acuity was assessed using the Rosenbaum Pocket Vision Screener (similar to a Snellen chart) at a distance of approximately 37 cm (14.5 in.). Participants were asked for any significant health problems including visual difficulties. None reported visual difficulties.

Display. — Stimuli were presented on a Zenith video monitor (Model ZVM-121). Participants viewed the display from a distance of 36.8 cm (14.5 in.). To maintain this distance, participants were instructed to keep their foreheads in contact with a guide strip, a cord stretched taut across the testing cubicle adjusted to the individual's forehead height. Nine young participants were run with a chin/head rest. When older pilot participants reported discomfort with the restraint, it was replaced with the guide strip. Fifteen additional younger adults were tested with the new procedure. Preliminary analyses showed no differences between the two groups of younger adults, so they were combined for all the results reported here. At the viewing distance used, the characters subtended .86 degrees vertically by .54 degrees horizontally. The characters were separated by .20 degrees. The first target extended 6.30 degrees in each direction from the center of the display. The central character of the second target appeared at fixation (0 degrees) and at 2.22 and 4.44 degrees to the left and to the right of fixation. (For comparison, Cerella, 1985, presented targets at 0, 1, 2, and 3 degrees from fixation; LaBerge, 1983, presented targets at 0, .37, and .74 degrees.) The luminance of the stimulus characters was approximately 10 cd/m^2; background luminance was approximately .2 cd/m^2, measured by a Spectra Pritchard Photometer (Model 1980).

Procedure. — The participant was instructed to fixate on the * when the warning stimulus appeared. The fixation remained on for 1000 ms. The first target was then presented for 200 ms with the central character in the same position as the * in the warning. The first target was followed by the second target, which was erased after 200 ms. An additional 1800 ms was allowed for a response. The task was to respond with a keypress if the first target consisted of Ss (in the unfocused conditions) or if the center character was an S (in the focused conditions) *and* the second target contained a 7. The participant was to withhold a response otherwise. The response rule was summarized as "Press the key if you see an S followed by a 7." Reaction time was measured from the onset of the second target. In all conditions, the participant was instructed to maintain the direction of gaze where the * had been in the warning stimulus. The two different focus conditions were introduced simply by describing the possibilities for the first target.

Each participant completed one block of focused trials and one block of unfocused trials. The order of the blocks was alternated for each successive participant in each age group. There were 55 trials in each block, the first 10 being practice. Both the first and second target display durations were gradually reduced from 1000 ms to 200 ms over the practice trials. The results from the practice trials were discarded. A rest period was given after each block. Of the 45 nonpractice trials in a block, 30 required a response (six at each of the five possible locations for the second target). Of the 15 nonresponse trials, five had an S in the first target but did not have a 7 in the second and 10 did not have an S in the first target. Trials with errors or misses were followed by a tone and the word "error" flashed on the display screen.

RESULTS

Preliminary examination of the data indicated that both reaction time and proportion of errors were affected by the independent variables, as Cerella (1985) also reported. Consequently, we decided to analyze both dependent variables simultaneously using multivariate analysis of variance (MANOVA). Age group was a between-subjects factor in the analysis, while focus condition (focused and unfocused) and target location in the second display (0, 2.22, and 4.44 degrees from fixation) were within-subjects factors. Reaction times and errors for corresponding points on the left and right sides of fixation were averaged.

There were significant main effects of age, Wilks' Λ = .40, $F(2,36) = 27.09, p < .001$, location, Wilks' Λ = .31, $F(4,34) = 18.97, p < .001$, and focus, Wilks' Λ = .50, $F(2,36) = 17.86, p < .001$. There were significant interactions of focus and location, Wilks' Λ = .70, $F(4,34) = 3.46, p = .018$, age and location, Wilks' Λ = .50, $F(4,34) = 8.58, p < .001$, age and focus, Wilks' Λ = .75, $F(2,36) = 5.92, p = .006$, and age, focus, and location, Wilks' Λ = .74, $F(4,34) = 3.05, p = .03$. Average errors are given in Table 2; average reaction times are shown in Figure 1. Table 3 gives the slope (in milliseconds/degree) of the line best fitting the eccentricity-reaction time function. The fits were obtained using a formula developed by LaBerge and Brown (1986). Ordinary regression with three equally spaced values of the predictor does not make use of the second point. In order to use information from all three points, LaBerge and Brown constrained the solution such that the reaction time at 0 degrees was the intercept of the line.

The correlations between reaction times and error rates were also examined for evidence of speed-accuracy tradeoffs. Across conditions, the average correlation was .15 for older adults and −.16 for younger adults. It is unlikely that the observed age differences reflect different balances of speed and accuracy.

The results showed that older adults were slower and made more errors than younger adults, that reaction times and errors increased with increasing target eccentricity, and that reaction times and errors were higher in the focused than in the unfocused conditions. The increases with increasing eccentricity were greater for older adults than for younger adults, and the difference between focused and unfocused conditions also was greater for older than for younger adults. The interaction of focus and location reflected the strong interaction of those two variables in the older adult group. The three-way interaction occurred because, for older adults, the increase in errors with increasing eccentricity was greater in the focused than in the unfocused condition. For younger adults, errors were unaffected by eccentricity in either focus condition.

DISCUSSION

There are two principal conclusions to be drawn from the results. The first is that Cerella's (1985) findings were replicated in the unfocused conditions. Older adults were slower and made more errors than younger adults. Moreover, reaction times increased more rapidly with increasing eccentricity for older adults than for younger adults. This eccentricity effect was also seen in the error rate for older

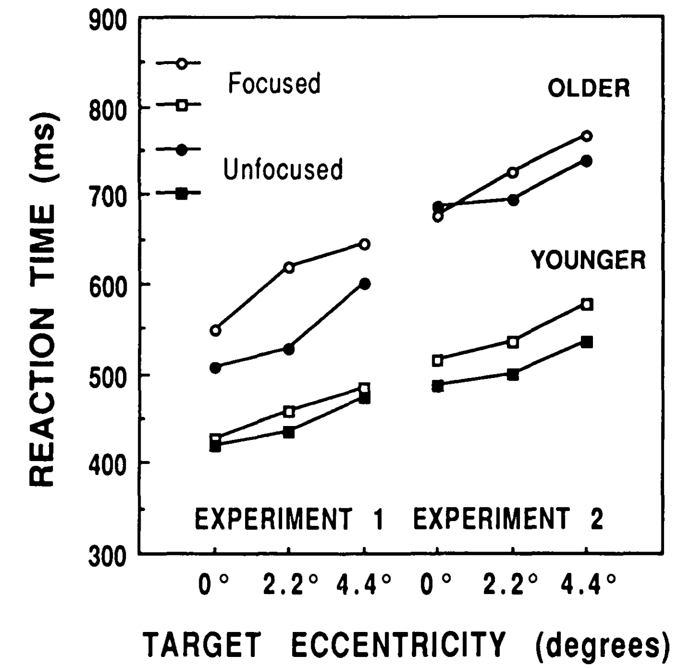

Figure 1. Reaction times as a function of age group, focus condition, and target location in Experiments 1 and 2. (Circles are older adults, squares are younger adults; unfilled symbols are focused conditions; filled symbols are unfocused conditions.)

Table 2. Average Proportion of Errors

	Narrow Focus			Wide Focus		
Location (Degrees from Fixation)	0	2.2	4.4	0	2.2	4.4
Experiment 1						
Older	.01	.13	.23	.00	.07	.08
Younger	.03	.02	.03	.00	.00	.00
Experiment 2						
Older	.02	.02	.02	.08	.03	.04
Younger	.03	.02	.03	.00	.00	.01

Table 3. Least-squares, Best-fit Slopes for Reaction Time as a Function of Eccentricity (milliseconds/degree)

	Narrow Focus	Wide Focus
Experiment 1		
Older	23.2	21.2
Younger	12.9	13.3
Experiment 2		
Older	18.6	10.0
Younger	10.8	10.3

adults, but not for younger adults. The second conclusion is that the interaction of age, focus, and location indicates the presence of age differences in attention distinct from the perceptual effects reported by Cerella (1985). It was as though, in the focused condition, the older adults were more tightly focused at fixation than the younger adults. One explanation for this is static: older adults may have allocated more attention to the center than younger adults. An alternative explanation is dynamic: the initial allocation may have been similar in the two age groups but older adults may have found it more difficult to disengage or may have shifted attention to the second target more slowly than younger adults.

The remaining question is why performance was overall better in the unfocused than in the focused condition. This may have been due to processing overlap; the target in the first display may not have been fully processed when the second display appeared. It seems likely that processing the first target when it is one character embedded in a field of different, featurally similar distractors would take longer than when it is surrounded by redundant characters. Consequently, the processing of the first target would be completed and full resources devoted to the second target sooner in the unfocused than in the focused conditions.

Experiment 2

It may have been that the 200 ms duration for the second target used in Experiment 1 (and by Cerella, 1985) was simply not sufficient for the older adults to extract the perceptual information from the display. The large age differences in error rates in the first experiment are consistent with this interpretation. A longer display time could compensate for the longer times needed for luminance integration and to escape masking in older adults. This was done in Experiment 2.

Method

The design and procedures in Experiment 2 were identical to those in Experiment 1 except that the second display remained on the screen for 2000 ms or until a response was given. The same individuals participated in this experiment as had participated in the first experiment.

Results and Discussion

The analysis was again a MANOVA on reaction times and error rates with age group as a between-subjects variable and second target location and focus condition as within-subjects variables. There were significant main effects of age, Wilks' $\Lambda = .48$, $F(2,36) = 19.68$, $p < .001$, location, Wilks' $\Lambda = .41$, $F(4,34) = 12.41$, $p < .001$, and focus, Wilks' $\Lambda = .82$, $F = 3.97$, $p = .028$. There were no significant interactions: focus and location, Wilks' $\Lambda = .86$, $F(4,34) = 1.36$, $p = .27$, age and location, Wilks' $\Lambda = .84$, $F(4,34) = 1.57$, $p = .20$, age and focus, Wilks' $\Lambda = .89$, $F(2,36) = 2.27$, $p = .12$, and age, location, and focus, Wilks' $\Lambda = .86$, $F = 1.33$, $p = .28$. Error rates are given in Table 2 and reaction times are shown in Figure 1; best-fitting slopes are given in Table 3. Reaction times were positively correlated with errors for both older and younger adults, .23 and .27, respectively, averaged across conditions. Again, it did not appear that either group was trading reduced accuracy for increased speed.

Once again, older adults were slower and made more errors, and reaction times increased with increasing target eccentricity and were longer in the focused condition. Unlike Experiment 1, the results did not show a greater increase in reaction time or errors with increasing target eccentricity in older adults than in younger adults. The age differences as a function of eccentricity that were obtained by Cerella (1985) and that were replicated in Experiment 1 were removed by allowing sufficient time for the stimulus to be perceived by older adults. This is consistent with the interpretation that older adults require more time to complete the processing of the first target, disengage attention, and move it to the second target.

The longer display duration in Experiment 2 could have permitted the participants to move their eyes, shifting fixation to the target in the second display before responding, although they were instructed not to do this. Had this occurred, the absence of age differences as a function of eccentricity could have resulted because all of the stimuli were processed foveally. It is unlikely that this occurred. If it had, reaction times should have been the same in Experiments 1 and 2 for the center target location because no eye movements would be required. Instead, reaction times were noticeably longer in Experiment 2. Further, reaction times to targets 2.22 degrees from fixation should have been longer than those to the center target by about the time needed to execute a saccade (180–250 ms, see Alpern, 1972); they were not.

General Discussion

The results of the unfocused conditions in the first experiment confirm Cerella's (1985) finding that reaction times increase more for older adults than for younger adults as the targets are located increasingly farther from the fovea. The important result is the interaction of age, focus, and location. The difference between the focused and unfocused conditions was greater for older than for younger adults. This shows that there are age differences in attention independent of the impaired peripheral processing found by Cerella.

Can we rule out the possibility of attentional differences in Cerella's results? It is possible that Cerella's procedures did not induce a broad focus encompassing the extent of the stimulus array. To be certain, a condition that had been previously shown to broaden the focus of attention should have been included. The results of another experiment we have performed address this issue. The procedures were identical to the unfocused condition in Experiment 1 except that the first target display was the word WHOLESALE rather than a string of 8s or Ss (see LaBerge & Brown, 1989, Experiment 3). The letters were spaced so that the horizontal extent was the same as the first display in Experiment 1. The task was to respond if both the word was spelled correctly and the second display contained a seven, and to withhold a response otherwise. The resulting slopes were 7.2 ms/degree for younger adults and 10.0 ms/degree for older adults. (In LaBerge & Brown's, 1989, results, the average slope was

7.1 ms/degree for conditions in which the second target was similar to those used here.) For younger adults, the similarity of this slope to those in both the focused and unfocused conditions of Experiments 1 and 2 suggests that they maintained a broad focus of attention despite the experimental manipulations. For older adults the slopes varied, indicating that, in some conditions, they adopted a narrow focus of attention while, in others, they could broaden their attention just as the younger adults did. These results point up the importance of controlling the focus of attention experimentally. Moreover, it would be desirable in future experiments, if results are to be attributed to perceptual rather than attentional factors, to induce a broad focus of attention.

It is clear that the age differences as a function of eccentricity can be removed by allowing sufficient time for the target to be processed by older adults. This means that the extrafoveal deficits found by Cerella (1985) and the attentional differences found here are due to older adults requiring differentially longer than younger adults to process stimuli outside the fovea, especially if unattended, rather than to structural differences such as impaired resolving power.

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