VISUAL DISPLAYS AND SELECTIVE ATTENTION: DO THE ELDERLY BENEFIT IF THE INFORMATION IS FLASHING?

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Report No. UMTRI-95-32
October 1995

Technical Report Documentation Page

1. Report No.
UMTRI-95-32

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Visual Displays and Selective Attention: Do the Elderly Benefit if the Information is Flashing?

5. Report Date
October 1995

6. Performing Organization Code
304118

7. Author(s)
Josef Schumann, Michael Sivak, Michael J. Flannagan, Masami Aoki, and Eric C. Traube

8. Performing Organization Report No.
UMTRI-95-32

9. Performing Organization Name and Address
The University of Michigan
Transportation Research Institute
2901 Baxter Road
Ann Arbor, Michigan 48109-2150 U.S.A.

10. Work Unit no. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
American Automobile Manufacturers Association
7430 Second Avenue
Detroit, MI 48202 U. S. A.

13. Type of Report and Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

People show substantial decrements in controlled processes with advanced age. However, there is evidence that automatic processes are more resistant to aging. The decline in controlled processes is likely to affect driving—a task that is dependent on efficient information processing. Consequently, older drivers could benefit if parts of the driving task can be designed so that they can be performed in an automatic way.

The present laboratory study investigated the effect of a flashing stimulus on its efficiency to attract the subject's attention in an automatic manner. There were two groups of subjects: sixteen older drivers with a mean age of 70, and sixteen younger drivers with a mean age of 29. They had to perform a two-alternative, forced-choice task, which involved responding to an arrow pointing left or right. The response time was measured for different arrow presentation modes (flashing vs. steady), workload conditions (with and without an additional tracking task), distracter conditions (with and without), and monitor locations (center vs. periphery of the visual field).

The results showed that flashing stimuli were not processed in an automatic manner. Although younger subjects benefited from the flashing in conditions in which the arrow was embedded among distracters, older subjects did not. This may be explained by age-related decrements in discrimination between relevant and irrelevant information.

Although the results of the present study do not clearly indicate specific ways in which the automatic/controlled processing distinction can be used to the advantage of older drivers, the most basic limitations of these results may be the lack of evidence for automatic processing by either young or old subjects. The controlled/automatic distinction remains potentially important. The present results suggest that the most promising strategy to exploit the distinction may involve a systematic task analysis that would identify what components of the driving task are performed most automatically.

17. Key Words
older drivers, displays, elderly, age, perception, attention, information processing, reaction time, automatic processes, controlled processes

18. Distribution Statement
Unlimited

19. Security Classification (of this report)
None

20. Security Classification (of this page)
None

21. No. of Pages
30

22. Price

ACKNOWLEDGMENTS

This study was supported by the American Automobile Manufacturers Association (AAMA).

CONTENTS

INTRODUCTION

Accident risk of older drivers

Although older drivers are able to drive safely and to be successful in avoiding accidents of almost all types, they have higher accident rates compared to younger drivers in complex traffic situations with a high task demand (Cerrelli, 1989; Stamatiadis and Deacon, 1995).

While this increased accident risk for older drivers in complex traffic situations can be partly attributed to declining visual abilities and biomechanical changes with age (Sivak et al., 1995), general information processing capabilities also have to be considered. Decisions and actions in complex driving situations are performed by the driver mainly at the guidance level of the driving task (Allen, Lunenfeld, and Alexander, 1971). A task at this level consists of the driver's responses to road and traffic situations, which has to be performed under a tight time schedule. While planning and executing maneuvers, the driving task has changed from a previously self-paced task to a forced-paced task, in which the timing of the different subtasks involved becomes crucial (e.g., making a left turn at an intersection). Because of age-related cognitive declines, the time required to act properly in a complex traffic situation is usually longer for older drivers, and they consequently have a greater likelihood of being involved in accidents.

Automatic vs. controlled processing

From the perspective of information processing, the driver has to perceive information and to process this information before responding. An important distinction has been made concerning whether this processing is accomplished in an automatic or a controlled fashion. Whereas automatic processing generally is described as being fast, parallel, and effortless, controlled processing on the other hand is slower, serial, and attention-demanding (Schneider, Dumais, and Shiffrin, 1984).

Applying the concept of automaticity to performance of a complex task must be done carefully, because a complex task, such as driving, consists of several component processes, at least one of which may be nonautomatic. To determine the contribution of automatic and controlled processes to the execution of a complex task, research questions therefore should not concentrate on the complex behavior as a whole, but be focused on the component processes (Jonides, Naveh-Benjamin, and Palmer, 1985; Salthouse, 1991).

In the following, automatic processing will be restricted to visual information acquisition (i.e., the perceptual encoding part of information processing). One automatic process involved in this stage has been termed stimulus-driven selection and is referred to as bottom-up or exogenous control (Yantis, 1993). Stimulus-driven attentional capture refers to the fact that certain properties of a stimulus may capture attention involuntary, irrespective of the intentions or goals of the observer (Yantis, 1993). One particular property that seems to capture visual attention automatically is the abrupt onset of a stimulus, i.e., an abrupt change in luminance over time. Abrupt onsets draw attention to these objects in the visual field and cause the observer to process abrupt visual events with high priority (Yantis and Jonides, 1990). This mechanism can become particularly important for older drivers, because it should speed up a task that relies on the selection, perception, and interpretation of information presented to the driver.

One of the major findings in gerontological research is that there are age related declines of controlled processes, whereas only minor decrements are present for automatic processes (Salthouse, 1992). The age-related decline in controlled processing has been attributed mainly to two mechanisms:

- the inability to suppress irrelevant information (Stoltzfus, Hasher, Zacks, Ulivi, and Goldstein, 1993), and
- a general slowing of central processing stages (Madden, 1992).

Relevance for the design of displays

In assessing the effect of advanced-technology information systems, it is critical to take into account cognitive capabilities of older drivers. What is the consequence of a new information display (e.g., a navigation system) or a warning device with regard to overloading older drivers' decision making and information processing capacities?

To attract the driver's attention to specific information within a display, the information has to be made conspicuous in relation to other competing visual information. This can be achieved by varying certain features of the relevant stimulus (e.g., form, color, or contrast). However, if the selection process has to be performed in a controlled fashion, an additional slowdown at this stage of information processing, and consequently a delay of the driving task at hand, can be expected for older drivers. On the other hand, if the newly introduced information can be processed in an automatic way, age-related decrements might be reduced or even eliminated.

Attracting the driver's attention in an automatic fashion should be facilitated only for relevant information. Stimulus features that automatically attract the driver's attention can be utilized, for instance, when the timing of the information processing becomes crucial. On the other hand, if the information to be conveyed to the driver is of only secondary importance and its execution can be delayed by the driver, it should not be designed to result in automatic processing. Under such circumstances an increased saliency of the relevant stimulus is all that should be sought. Therefore, there is always a trade-off in the proper use of features that lead to automatic or controlled processes, depending on the importance of the information to be presented.

Research questions

The present study was designed to investigate the effects of stimulus-driven attentional capture on younger and older subjects. In a laboratory study, subjects had to perform a simple forced-choice task. The task required them to detect an arrow on a screen, identify its direction (left vs. right), and respond to it appropriately. A flashing arrow was chosen to represent stimulus-driven attentional capture, and the main research question was whether older drivers would benefit from this presentation mode.

Even if performance of the task were to be improved by flashing, the overall response time of older subjects to such a flashing arrow was still expected to be slower than that of younger subjects, because response selection in a choice reaction time task exhibits considerable age-related slowdown (Kausler, 1991).

Further research questions were concerned with the performance of the forced-choice task under different workload conditions, and the identification of the arrow when it was embedded in irrelevant information. Both conditions can be used to test the load-insensitivity criterion for assessing automatic processing (Palmer and Jonides, 1988). Performance based on automatic processing should be relatively insensitive to higher workload or to the amount of concurrent information in a task. If, however, the performance on the task is based on controlled processing, older subjects should show a significant decline with higher workload and increasing concurrent information compared to younger subjects.

METHOD

Subjects

Thirty-two paid subjects, all licensed drivers, participated in the study. There were two age groups, each consisting of sixteen subjects balanced by sex. Subjects were recruited from lists that we maintain of potentially interested subjects, as well as from a newspaper advertisement.

The ages of subjects in the younger group ranged from 24 to 38 years (mean = 28.5; standard deviation = 4.1), and in the older group from 58 to 77 years[1] (mean = 69.8; standard deviation = 6.0).

All subjects wore the same eyewear, if any, that they would normally wear when driving.

Task

Subjects performed a two-alternative, forced-choice task. The task involved responding to the direction of an abruptly presented arrow as quickly as possible by pressing a response button. During half of the trials the subjects also had to perform a secondary tracking task. The tracking task, which was similar to steering a car down a winding road, was presented on a television screen.

Equipment

Schematic diagrams of the experimental setup and subject's view are shown in Figures 1 and 2.

A 69-cm television monitor that displayed the tracking task was located directly in front of the subject at a distance of 3 m. Subjects controlled the tracking task with a steering wheel. They were asked to hold the steering wheel in such a way that they easily could press with their thumbs two response buttons that were located on the spokes inside the steering wheel. Eye position was kept approximately constant across subjects by adjusting the height of the seat so that they could see a small white fixation point right below the television monitor (see Figure 2). After the eye position was adjusted correctly, subjects were asked to lean their heads backwards against a headrest.

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[1] Most of the older subjects were between 65 and 75 years. Two subjects were younger than 65 (58 and 60 years), and two were older than 75 (77 and 79).

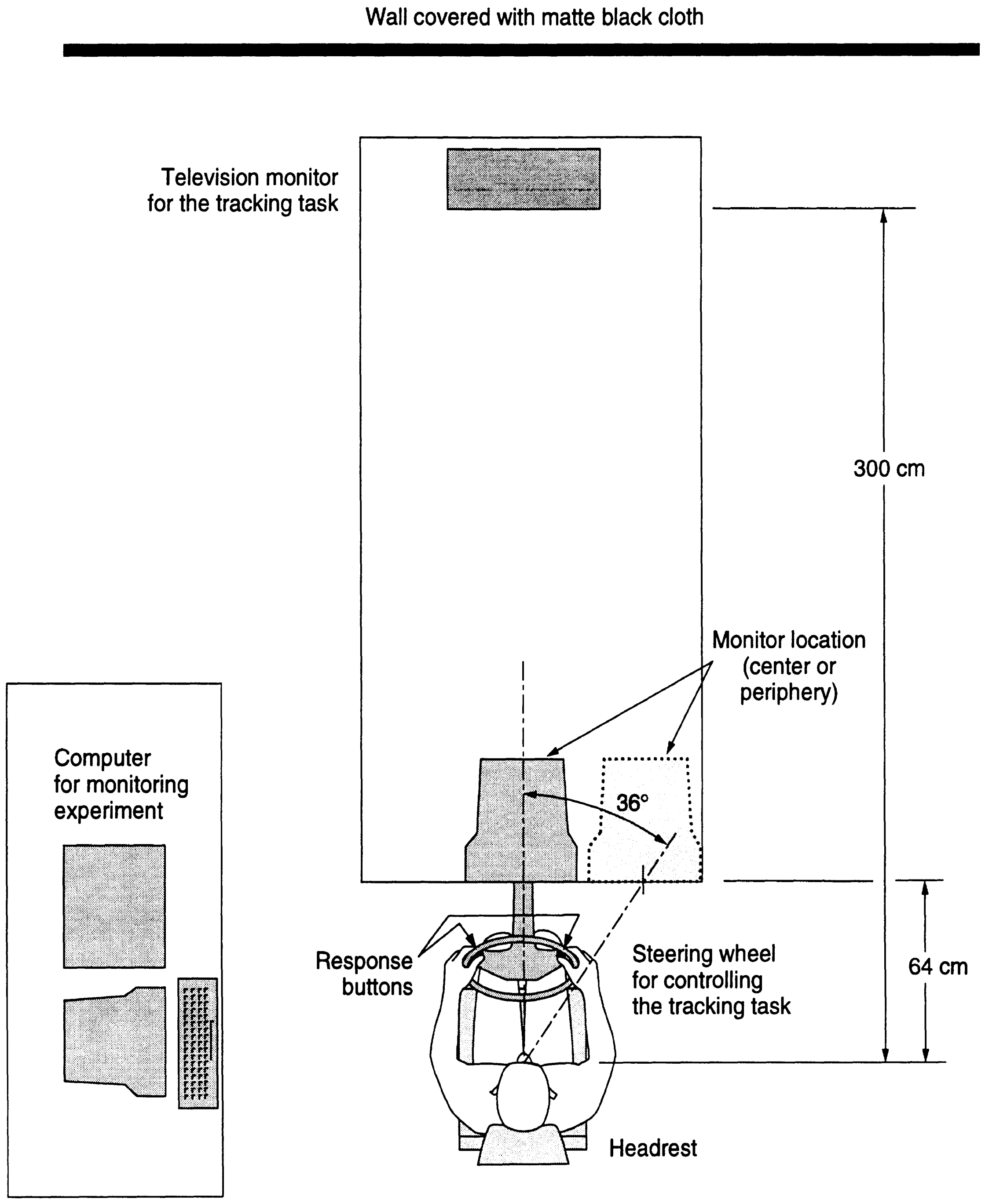

Figure 1. A schematic diagram of the experimental setup.

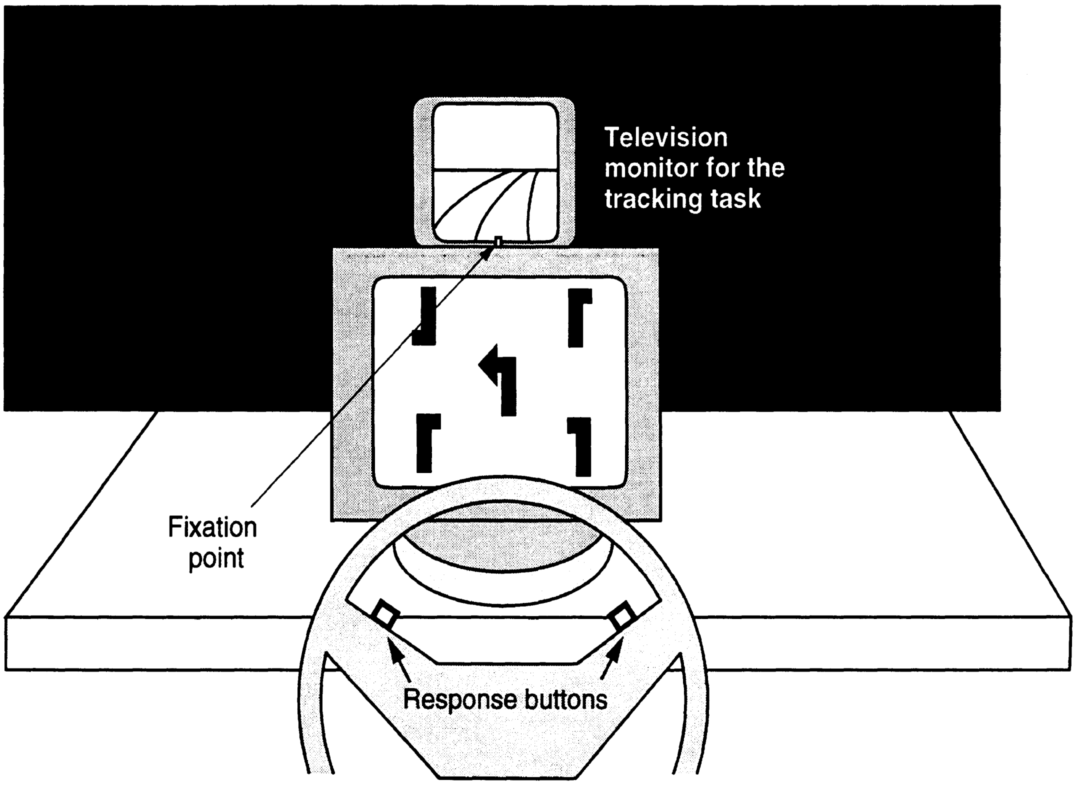

Figure 2. A schematic diagram of the subject's view, showing the monitor with the identification task in the center position.

Arrows for the forced-choice task were presented on a 38-cm monitor that was located 64 cm in front of the subject. There were two possible monitor positions, either directly in front of the subject, or to the right at an angle of 36° measured center-to-center (see Figure 1).

Overhead fluorescent lights were on throughout the experiment. In order to prevent the reflection of those lights from appearing on the television monitor, a black board was placed around the monitor. A matte black cloth covered the wall that was immediately behind the tracking-task monitor.

Two computers were used for the study, one (IBM-compatible 286 PC) to control the tracking task, and another (Macintosh Performa 636 CD) to collect response data and to control the presentation of the arrows for the main task. A CMU button box (version Mk VI) was employed, which allowed response times to be recorded with millisecond accuracy. To present the arrows, and to control the experiment, the PsyScope software (version 1.0.2) was used (Cohen, MacWhinney, Flatt, and Provost, 1993). Data from the tracking task were not recorded.

Stimulus conditions

On each experimental trial, subjects had to respond to an arrow that pointed either to the left or to the right (see Figure 3). The arrows were black on a white background.

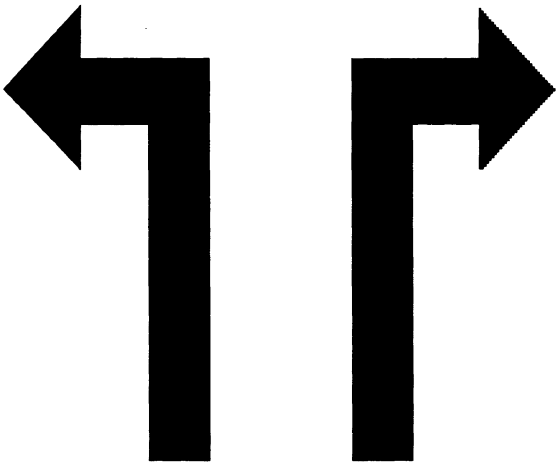

Figure 3. The two possible arrow stimuli (arrow tail: 50 mm x 8 mm, arrow head: 26 mm x 22 mm).

The arrow was presented in one of two presentation modes :

(1) steady, in which the arrow was presented for one second, or

(2) flashing, in which the arrow was flashing at a rate of 6.25 Hz[2] for 480 msec (80 msec on, 80 msec off; three complete cycles), and then remained steadily on for an additional 520 msec.

In one of the experimental conditions the arrow was presented together with a set of four similar distracters (see Figure 4). Each of the four distracters was always chosen randomly from the complete distracter set (e.g., all distracters could be the same, or they could be all different). With four distracters and one arrow, five possible objects could appear on the monitor. Therefore, the monitor was divided into five portions of equal size. Arrows and distracters—if present—appeared in the center of each of the five screen positions (left top, left bottom, center, right top, right bottom; see Figure 5).

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[2] The vertical refresh rate of the monitor was set to 67 Hz at a resolution of 640 x 480.

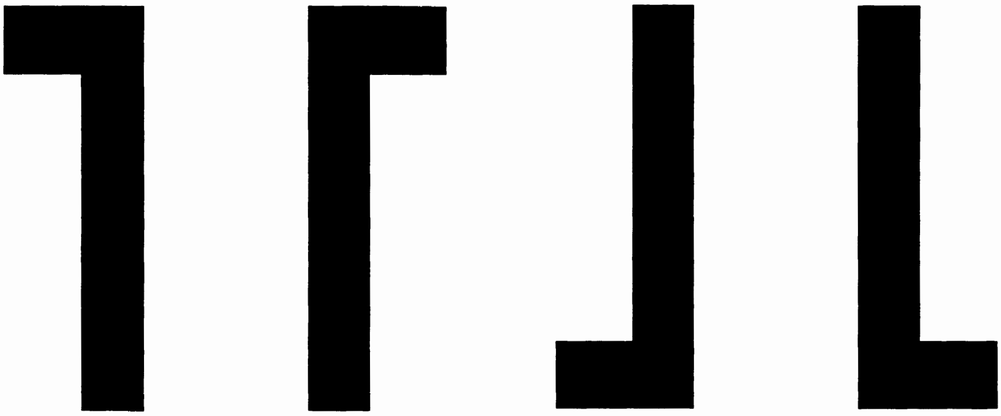

Figure 4. The four possible distracters (tail: 50 mm x 8 mm, side part: 10 mm x 8 mm).

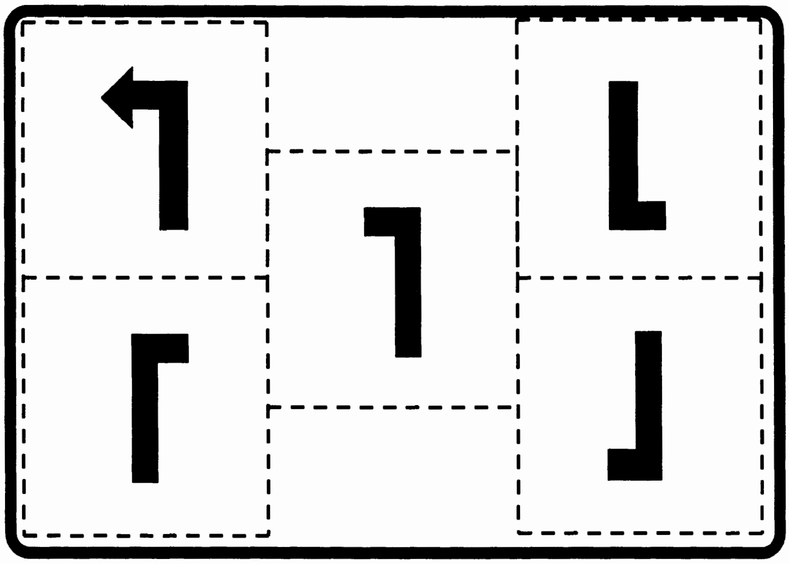

Figure 5. Example of an arrow stimulus presented with distracters (scaled down). The dashed lines (not present in the experiment) separate the five possible screen positions.

Experimental design

The following independent variables were factorially combined:

(1) Age, a between-subjects variable with two levels (younger, older).

(2) Presentation mode, a within-subjects variable with two levels (steady, flashing).

(3) Distracters, a within-subjects variable with two levels (no, with).

(4) Workload, a within-subjects variable with two levels (high, low). The different workload conditions were operationalized by the presence or absence of the tracking task.

(5) Monitor location, a within-subjects variable with two levels (center, periphery).

The combination of the two workload levels and the two monitor locations made up four experimental conditions that were presented as blocks of trials. The order of the monitor-location blocks was balanced across subjects, while the low-workload block always preceded the high-workload block.

Each block consisted of 40 trials, and the order of those 40 trials was randomized. Each of the four combinations of two levels of presentation mode and two levels of distracters was presented ten times, varying the direction of the arrow pointing either to the left or to the right, and presenting each arrow once at the five possible positions on the monitor (see Figure 5). As an example, the presentation order for one subject is shown in Figure 6.

low workload **monitor location: center**	**high workload** **center**	**low workload** **periphery**	**high workload** **periphery**
- **presentation mode** (steady, flashing) - **distracters** (no, with) - **arrow pointing** (left, right) - **screen position** (left top, left bottom, center, right top, right bottom)	. . . .	. . . .	. . . .
40 trials randomized	40 trials randomized	40 trials randomized	40 trials randomized

Figure 6. A sample presentation order of the four experimental blocks (each block 40 randomized trials).

Procedure

The experimenter read the instructions to the subject. The subject was instructed to perform the tracking task by keeping a simulated winding roadway centrally located on the television monitor. The two-alternative, forced-choice task was then introduced. Subjects were instructed to respond to the arrow as quickly as possible, but also to make correct responses. They were told to press the left button if the arrow pointed to the left, and to press the right button if the arrow pointed to the right. The steering wheel was limited in its movement to 35° in each direction, and, therefore, the left-right spatial relationship between the response buttons and the arrow direction was maintained.

While the subjects performed the experimental task, they had to keep their eyes fixated at a small fixation point that was located at the bottom of the distant television monitor. They were asked not to turn their head or eyes towards the monitor where the arrow was presented.

Subjects were allowed to practice the tracking task until they felt comfortable with it. In the next step, they received a practice block of ten trials in which they had to respond to the arrows and to perform the tracking task at the same time. They could repeat this practice block if necessary. It was stressed that they should focus during all trials on the white fixation point located centrally below the television monitor. Once subjects felt comfortable with both tasks, the data collection began.

The dependent variable was response time, measured from when the arrow appeared until the subject pressed one of the buttons on the steering wheel. Incorrect responses were also recorded. If the subjects responded incorrectly, a short alarm tone was presented. Responses longer than three seconds were recorded as missing data. There were eight lengths of intertrial intervals, 6, 7, 8, 9, 10, 11, 12, and 13 seconds. These intervals were randomized, so that the time of appearance of the next arrow appeared unpredictable to the subject. Short breaks were given between blocks, during which the experimenter also could change the monitor if needed.

RESULTS

Overview

The data were first analyzed for incorrect responses and missed trials. Data from correct trials were then examined for possible effects of the two arrow directions and the five different screen positions. Only small differences in the response times to the arrow directions, and the same patterns of how to respond to an arrow depending on its screen position (i.e., faster responses to those arrows that were closest to the subject's fixation point), were found. Therefore, the trials were combined, and the average response times for each of the experimental conditions distinguished by presentation mode, distracters, workload, and monitor location were calculated for each subject.

Analyses of variance (mixed design) were then used to examine the effects of age, presentation mode, distracters, workload, and monitor location on the subjects' response times. Separate analyses of variance were done for the two monitor locations to contrast a possible influence of the monitor location on the response behavior.

Incorrect responses and missing data

For the entire group of 32 subjects there were 32 missed trials (0.6 %), with almost half of the missed trials (15) for the older subjects when the monitor was in the periphery. Half of the subjects did not have any missed trials. Because there were so few missed trials, they were combined with the incorrect responses.

There were 223 incorrect responses (4.4 %), for a total of 255 (5.0 %) missed trials or incorrect responses. No subject had more than seven missed or incorrect responses in any one block of 40 trials. Furthermore each subject had at least two correct responses for each arrow direction[3] (out of the five different screen positions, see Figure 5). A summary of the incorrect and missing responses is shown in Figure 7.

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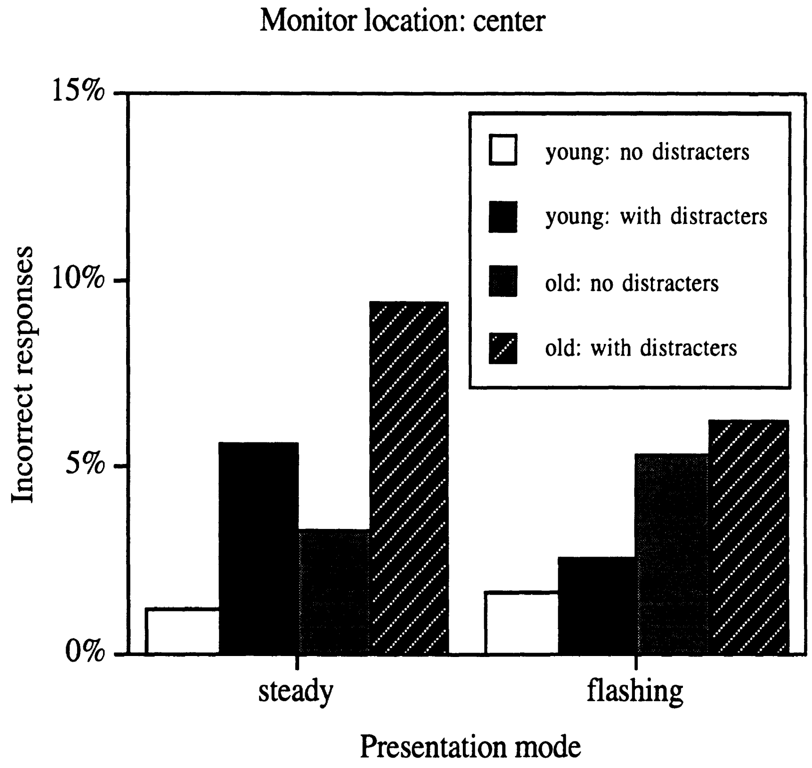
[3] Because we planned to combine the data of the five different screen positions as repetitions, we needed at least one correct response to avoid missing data.



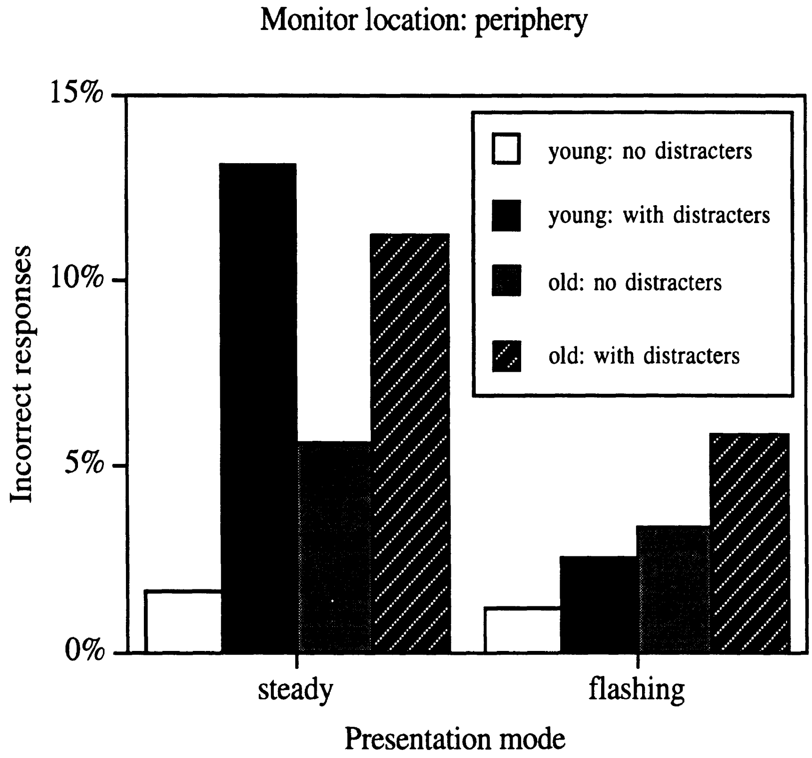


Figure 7. Percentages of incorrect responses (including missed trials) for different conditions.

These data indicate the following:

(1) the monitor location had no influence on the number of missed or incorrect responses;

(2) older subjects had more missed or incorrect responses than younger subjects;

(3) distracters increased the likelihood of missed or incorrect responses, especially for steady arrows;

(4) missed or incorrect responses were more frequent for steady arrows;

(5) younger subjects had a disproportionate percentage of missed or incorrect responses when steady arrows were presented together with distracters.

This higher error rate for the younger subjects however does not necessarily reflect an increased difficulty, but could be the result of a change in their response strategy. Instead of responding accurately, younger subjects could have responded faster to the steady arrows which could have resulted in a higher error rate. We will have another look at this hypothesis after presenting the results of the response-time data.

Combining data

Before combining results for the two different arrow directions, we checked whether there was an effect of arrow direction. The results are shown in Figure 8. Because the differences were small (maximum of 30 msec for older subjects with the monitor in the center location), the data were combined for further analysis.

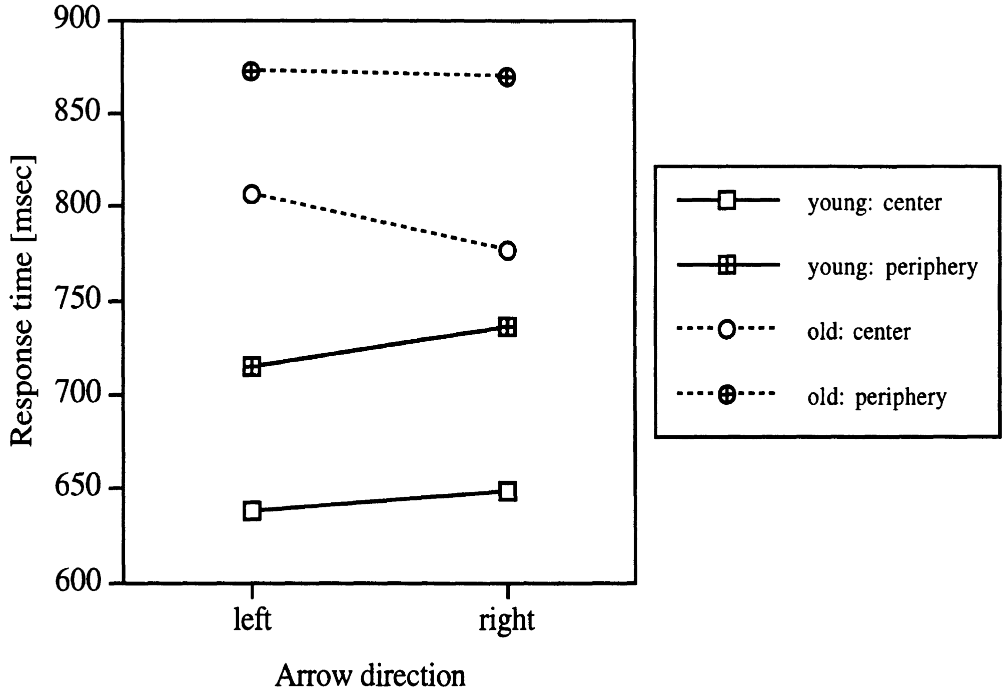
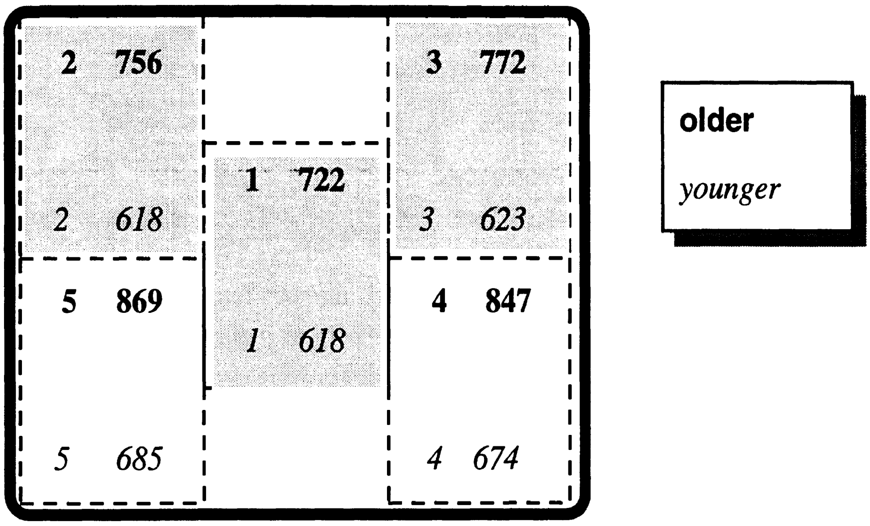
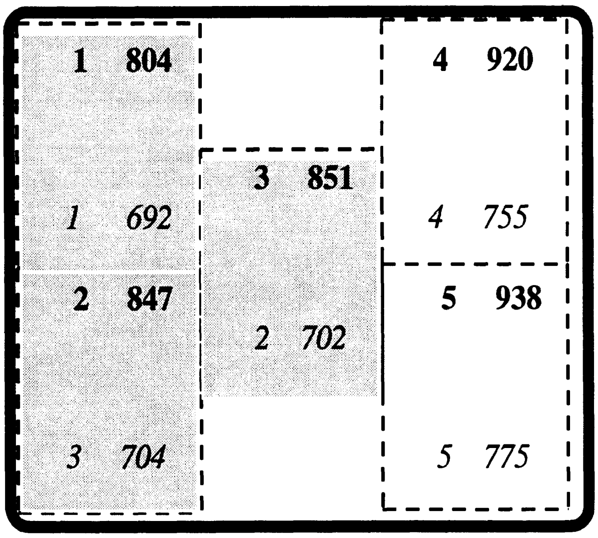


Figure 8. Average response times to the arrow direction for selected experimental conditions.

Next we checked possible effects of monitor location and position of the arrow on the monitor screen. The data are summarized in Figure 9. Although there was—as expected—an effect of monitor location, this effect was the same for both age groups. When the monitor was located in the center, subjects responded fastest to those arrows that were closest to their fixation point (i.e., the arrows appearing at the top of the screen, just below the fixation point on the more distant tracking task monitor; see the shaded areas in the top panel of Figure 9). When the monitor was located in the periphery, subjects again responded fastest to those arrows that were closest to their fixation point (i.e., the arrows appearing at the left part of the screen; see the shaded areas in the bottom panel of Figure 9). Since the response pattern was consistent across age groups, data were combined for further analysis.



Monitor location: center



Monitor location: periphery

Figure 9. Average response time to the arrow by the position on the screen (fastest screen positions are shaded). The left number in each screen position depicts the order of the response times, the right number the average response time in msec. Numbers for older subjects are in italics.

Analysis of variance

When there were no incorrect responses or missed trials, 10 trials (5 screen positions x 2 arrow directions) have been combined for each independent factor level to an average response. When there were incorrect responses or missed trials, the remaining correct trials have been combined.

Separate analyses were made based on the means and medians of those sets of response times. Because these analyses led to similar results, only the analyses based on means are presented here.

In a first step, we performed a 6-factor analysis of variance that included sex as an independent, between-subjects variable. Because the ANOVA did not result in significant sex differences ($F_{1,28} = 1.825$, $p = .19$) or in any significant interaction effects involving sex, men and women were combined for both age groups[4]. This led to a new 5-factor analysis of variance. This analysis incorporated one between-subjects variable (age) and four within-subjects variables (presentation mode, distracters, workload, and monitor location). Statistically significant results of this ANOVA are summarized in Table 1.

Table 1. Statistically significant results of the 5-factor ANOVA.

Factor	df	F	p
age	1,30	22.1	.0001
monitor location	1,30	56.9	.0001
presentation mode	1,30	11.4	.002
distracters	1,30	507.9	.0001
presentation mode * age	1,30	11.7	.0018
monitor location * presentation mode	1,30	6.2	.019
monitor location * distracters	1,30	8.6	.0065
presentation mode * distracters	1,30	41.8	.0001
mon.loc * workload * pres.mode	1,30	6.2	.018

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[4] It should be noted, however, that women responded somewhat more slowly than men (mean response times were 781 msec for females and 739 msec for males), and the difference was greater for older subjects (863 msec vs. 802 msec) than for younger subjects (699 msec vs. 676 msec).

All main effects, except workload, were significant. Older subjects responded more slowly than younger subjects (833 msec vs. 687 msec). Responses when the monitor was located centrally were faster than responses when the monitor was located in the periphery (719 msec vs. 802 msec). Subjects responded faster to the flashing arrow than to the steady arrow (745 msec vs. 775 msec). Distracters slowed responses considerably (863 msec vs. 657 msec).

As expected, the presentation mode affected the subjects' response behavior, but only when the arrow was presented with distracters. This interaction is shown in Figure 10.

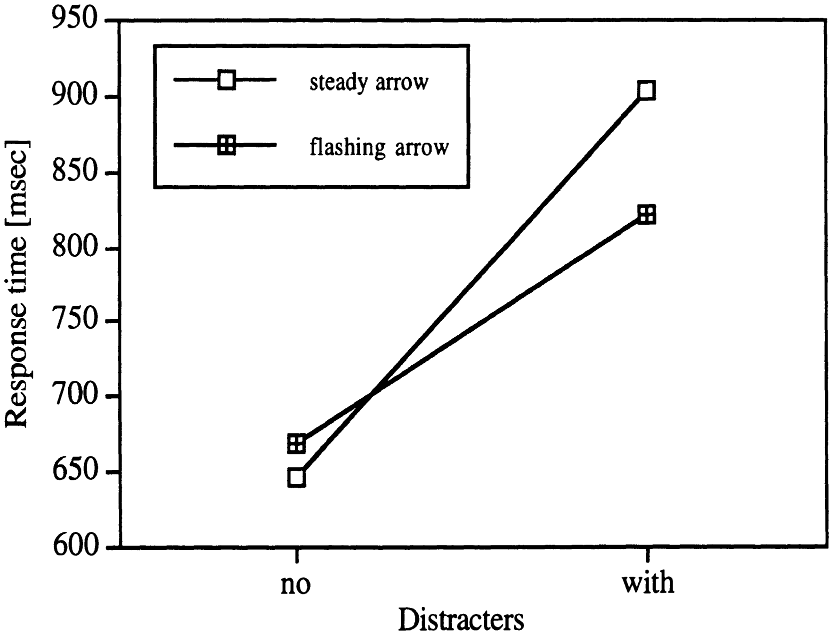

Figure 10. Mean response time by presentation mode of the arrow and distracters.

A post-hoc analysis revealed that the differences of five of the six pairwise comparisons involving presentation mode and distracters were significant. The exception was the difference between the steady and the flashing arrow condition without distracters [HSD[5](4,30) = 63.41 msec; $\alpha = 0.05$].

The significant interactions of presentation mode with age and monitor location are depicted in Figures 11 and 12.

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[5] HSD: Tukey's **H**onestly **S**ignificant **D**ifference test (Kirk, 1982).

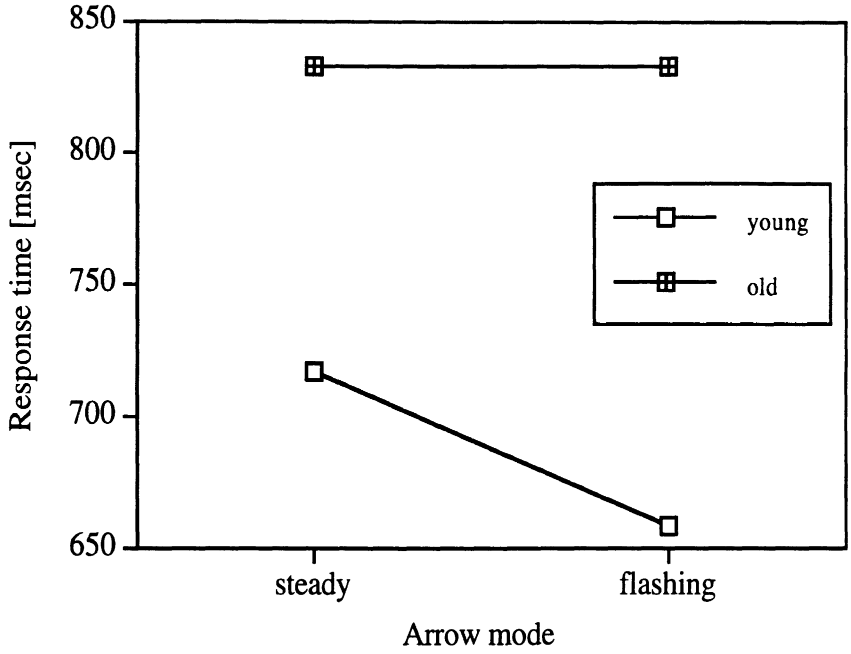

Figure 11. Mean response time by presentation mode of the arrow and age.

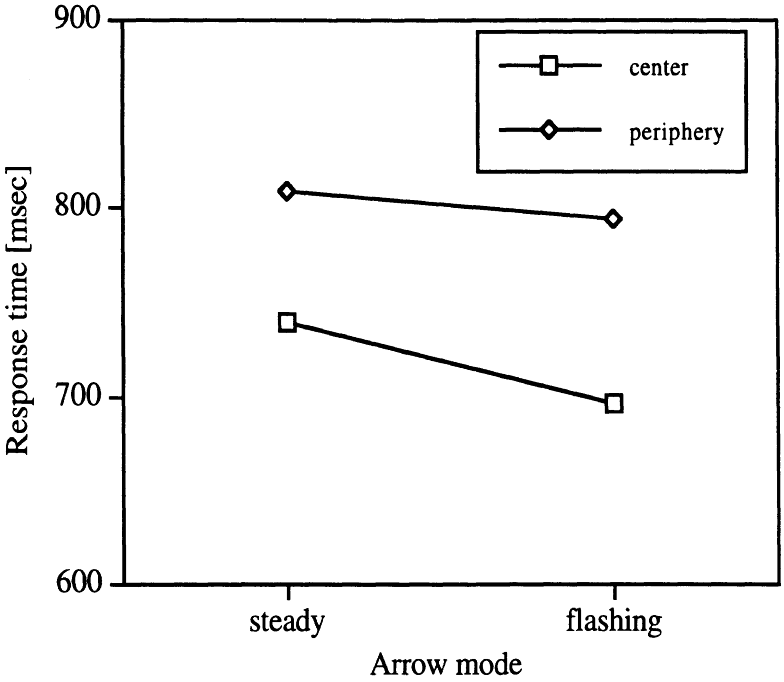

Figure 12. Mean response time by presentation mode of the arrow and monitor location.

Post-hoc Tukey tests of the interaction between presentation mode and monitor location showed that the differences between steady and flashing arrows are significant only in the center location [HSD (4,30) = 41.83 msec; $\alpha = 0.05$].

Because the location of the monitor where the arrow was presented had a large influence on how fast subjects responded to the two arrow presentation modes, we decided to perform a separate analysis of variance for each of the monitor locations. This led to two 4-factor analyses of variance, each with one between-subjects variable and three within-subjects variables. The significant results of these ANOVAs are summarized in Tables 2 and 3.

Table 2. Significant results of the 4-factor ANOVA (monitor location: center).

Factor	df	F	p
age	1,30	21.3	.0001
presentation mode	1,30	23.4	.0001
distracters	1,30	765.7	.0001
presentation mode * age	1,30	5.9	.022
distracters * age	1,30	5.5	.026
workload * presentation mode	1,30	5.6	.024
presentation mode * distracters	1,30	39.3	.0001

Table 3. Significant results of the 4-factor ANOVA (monitor location periphery).

Factor	df	F	p
age	1,30	18.0	.0002
distracters	1,30	263.2	.0001
presentation mode * age	1,30	11.0	.0024
presentation mode * distracters	1,30	24.1	.0001

Comparing Tables 2 and 3 reveals that the presentation mode of the arrow does not have significant influence in the periphery (see also the significant location by presentation mode interaction in Table 1 and Figure 12). Furthermore, the presentation mode and workload interaction is significant only in the center location (see also the significant location by workload by presentation mode interaction in Table 1). This interaction is shown in Figure 13.

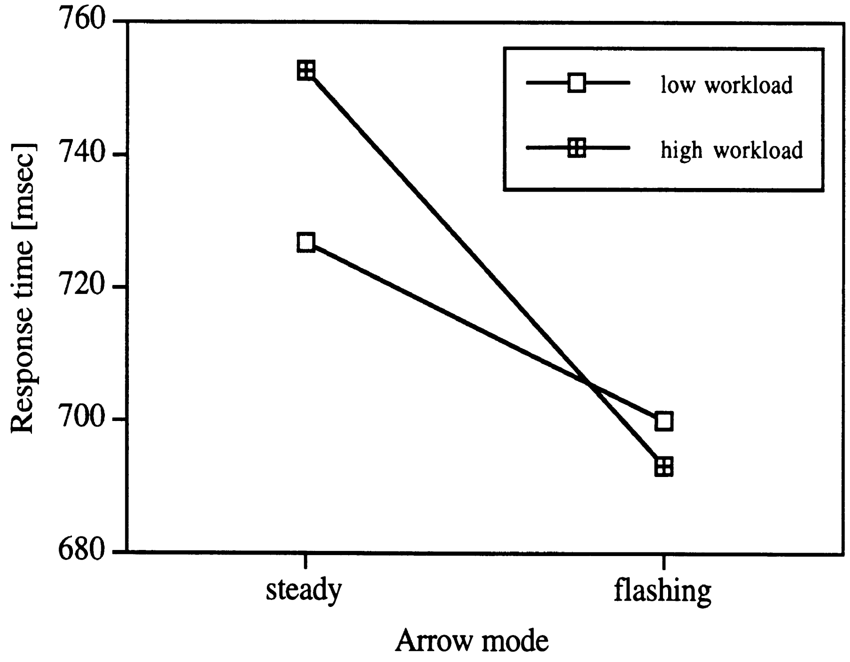

Figure 13. Mean response time by presentation mode of the arrow and workload (monitor location: center).

Post-hoc Tukey tests of the interaction between presentation mode and workload showed that the differences between steady and flashing arrows are significant under only high workload (i.e., with tracking task) [HSD (4,30) = 37.21 msec; $\alpha = 0.05$].

While the interaction of presentation mode and distracters shows the same effects no matter where the monitor is located (see also Figure 10), a different tendency appears when looking at the interaction of presentation mode and age separately for the two monitor locations. This can be seen in Figures 14 and 15.

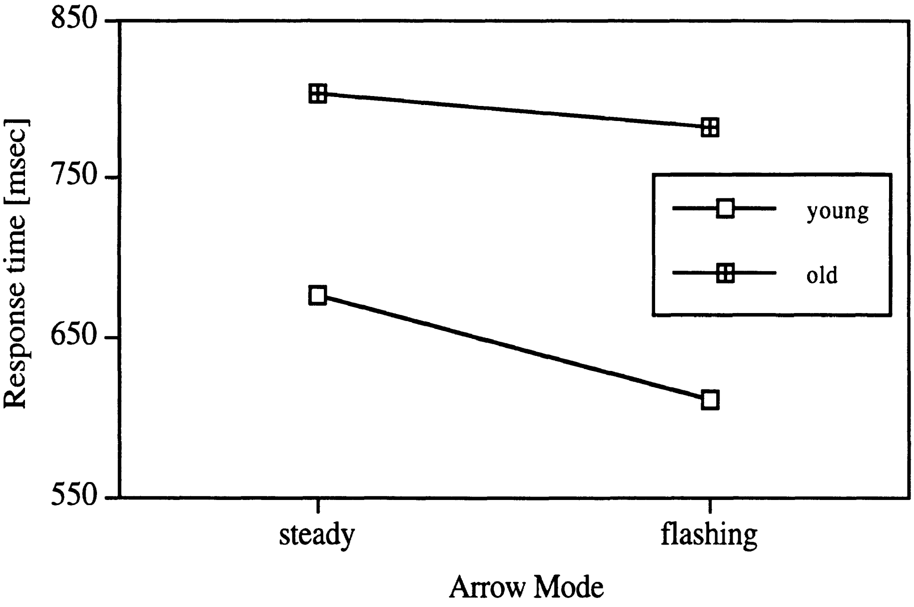

Figure 14. Mean response time by presentation mode of the arrow and age (monitor location: center).

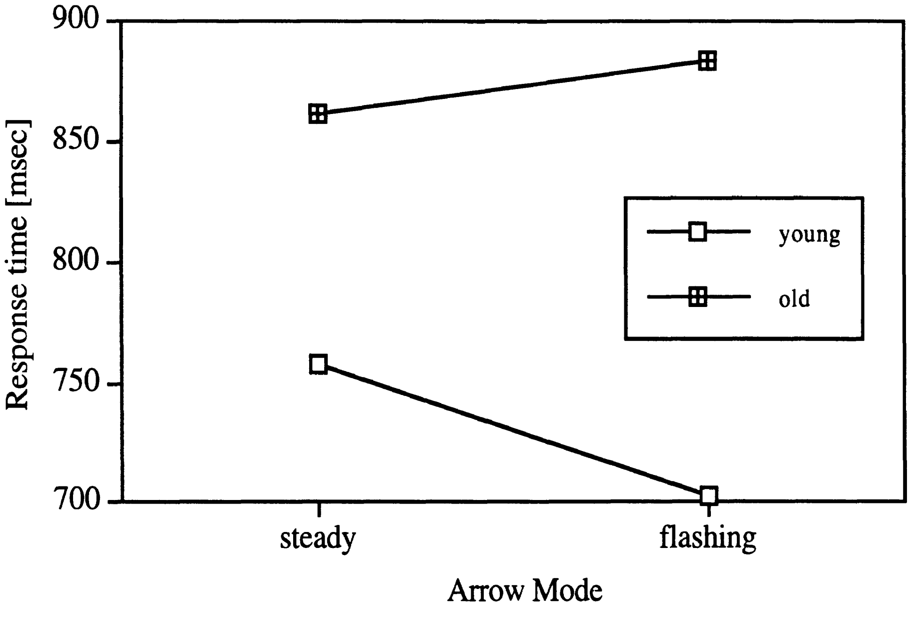

Figure 15. Mean response time by presentation mode of the arrow and age (monitor location: periphery).

While the tendency for the young subjects to respond faster to a flashing arrow is present no matter where the monitor is located, a different trend is evident for the older subjects. For them, flashing lowers the response time somewhat when the monitor is located in the center (see Figure 14), but it increases the response time when the monitor is in the periphery (see Figure 15).

Younger subjects showed an increased error rate when they had to respond to a steady arrow that was presented in the periphery (see Figure 7). They could have switched their response strategy for that particular condition towards more incorrect, but faster, responses (i.e., a speed-accuracy tradeoff). To examine this possibility, Figure 16 depicts the response behavior of younger subjects to a steady arrow for the two different monitor locations. A possible change in strategy seemed to have no influence on the order of the four arrow-presentation conditions. Independent of the monitor location, younger subjects still had their longest response times when confronted with a steady arrow embedded among distracters.

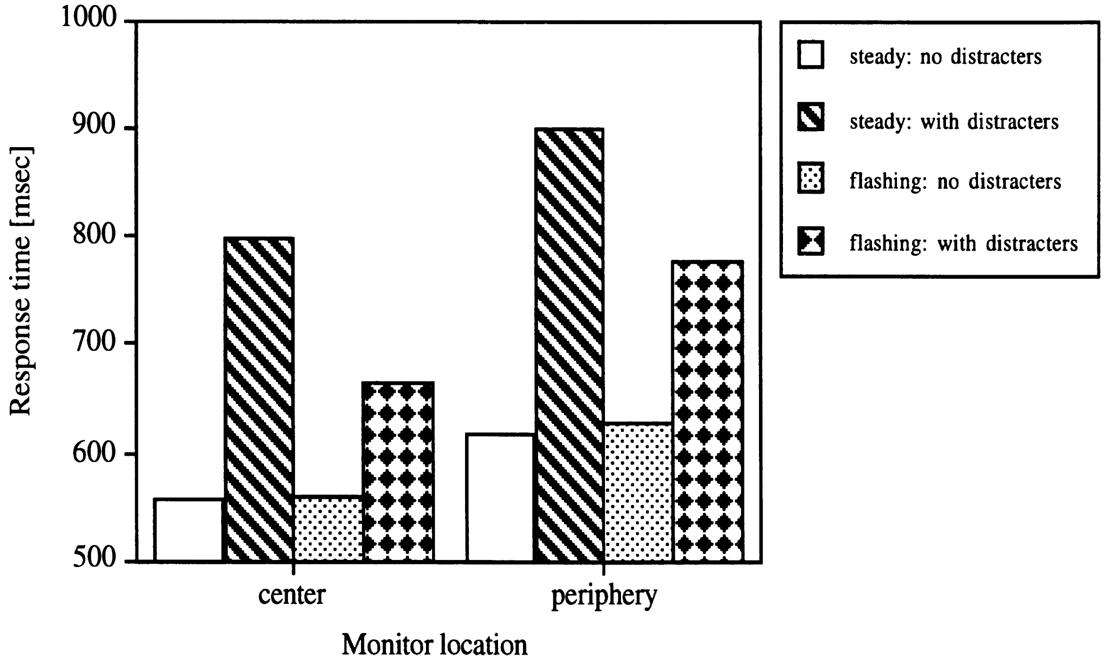

Figure 16. Mean response time to the two different arrow modes for younger subjects, shown separately for the two monitor locations (center and periphery).

DISCUSSION

The results indicate that all experimental factors, with the exception of workload, affected the subjects' response time. Younger subjects responded more quickly than older subjects. The closer the display monitor was placed to the fixation point, the faster subjects responded. It took subjects longer to respond to an arrow that was embedded among distracters. A flashing arrow speeded up the responses compared to a steady arrow.

Only workload, as it was operationalized in this experiment by the presence or absence of a concurrent tracking task, did not significantly influence the subjects' response behavior. An explanation for this unexpected result could be that controlling the tracking task was rather easy, and therefore the subjects had enough spare resources to respond as quickly and as accurately as possible to the arrow.

Before discussing significant interaction effects, especially those involving subject age, a closer look at the experimental task from an information processing perspective may be helpful. A schematic diagram of the main information processing stages is shown in Figure 18.

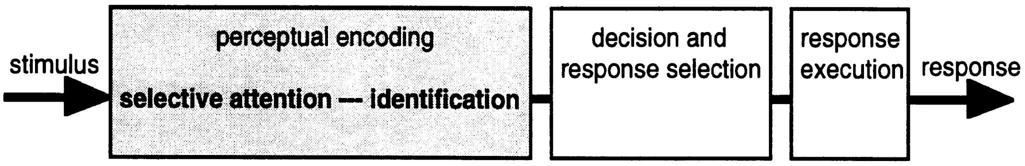

Figure 18. Schematic information processing stages of the experimental task.

Our manipulation involved the perceptual encoding stage only, keeping the decision and response selection, as well as the response execution stages, unaffected. In the perceptual encoding stage two subtasks had to be accomplished by the subjects:

(1) They had to locate an arrow appearing on the monitor (i.e., selective attention); and

(2) they had to identify the direction the arrow was pointing (i.e., identification).

Our hypothesis was that an abrupt onset, operationalized as a flashing arrow, would automatically direct visual attention to that stimulus, and that the subject would process the abrupt stimulus with high priority (Yantis and Jonides, 1990). As a consequence, the perceptual encoding stage should benefit from flashing.

Although subjects responded faster in the distracter conditions to the flashing arrow as compared to the steady arrow (see Figure 10), this cannot be unequivocally attributed to an automatic attention-capturing process due to the flashing. The results shown in Figure 10 do not support the load-insensitivity criterion for automatic processing (see Palmer and Jonides, 1988), which would require a zero slope connecting the two distracter conditions. However, because there is a decrease in the slope of the data for the flashing arrow compared to the steady arrow (see Figure 10), a flashing arrow seems to be more conspicuous than a steady arrow when presented together with distracters and, consequently, it can accelerate the visual search task, which requires selective attention.

More importantly, because visual search is required even with the flashing stimuli, older subjects should be at a clear disadvantage compared to younger adults (Plude and Hoyer, 1986; Plude and Doussard-Roosevelt, 1989). As can be seen in Figure 11, older subjects do not benefit from the flashing arrow compared to younger subjects. Because flashing does not automatically capture the subjects' attention, a disadvantage of older subjects can be attributed to age differences in attentional inhibition, which is responsible for this age-related slowdown (Kane, Hasher, Stoltzfus, Zacks and Connelly, 1994). The inefficiency of the flashing arrow for the older subjects can be explained by their diminished ability to ignore irrelevant background information and to discriminate relevant from irrelevant stimuli (Fisk and Rogers, 1991).

Taking into account that flashing did not lead to an automatic attention capturing, the effects of flashing should be even more apparent when the display monitor is moved to the periphery. This trend can be seen in comparing Figures 14 and 15. While there still is an advantage of the flashing for younger subjects (see the almost identical slopes for younger subjects), flashing does not have any benefit for older subjects (even a suggestive reverse trend is visible). This result may reflect the older subjects' declining ability of controlled information processing in the periphery, as postulated for example in the age-related decline of the useful field of view (Owsley, Ball, Sloane, Roenker and Bruni, 1991).

However, there seems to be a tendency that the identification of the arrow direction (i.e., the second stage in perceptual encoding in Figure 18) has been impaired by the flashing (see the response times to the flashing arrow in the no distracter condition in Figure 10). Therefore, an attempt should be made to exclude any possibilities that could impede the identification of relevant information after the attention has been drawn to the locus of a conspicuous object.

SUMMARY AND OUTLOOK

Although flashing can be used as a stimulus feature to increase the saliency of a stimulus, the results of this study suggest that flashing, as it was operationalized in this experiment, does not automatically capture visual attention. Therefore, flashing of relevant information does not appear to benefit older subjects (in contrast to younger subjects), because it still requires controlled selective attention processes.

However, these conclusions should be considered cautiously, because we cannot exclude the possibility that a benefit of flashing in the selective attention stage was obscured by a disadvantage of flashing during the identification stage. In other words, the flashing of the complete arrow might have impaired the identification of the arrow direction.

This problem might be avoided by flashing only a part of the object. The flashing part should not include any important information, which means, in our example, that only the stem of the arrow might be flashing, but not the arrow head.

On the other hand, because we are looking for stimulus features that automatically capture the observer's attention to improve the performance of older subjects, another feature or property of an object could be compared to abrupt onsets. Theeuwes (1994) has argued that any feature that is salient enough can preattentively (i.e., automatically) direct a subject's attention to the locus of an object. Therefore, for example, a different color could be used to distinguish important from unimportant information.

Although the results of the present study do not clearly indicate specific ways in which the automatic/controlled processing distinction can be used to the advantage of older drivers, the most basic limitations of these results may be the lack of evidence of automatic processing by either young or old subjects. The controlled/automatic distinction remains potentially important. The present results suggest that the most promising strategy to exploit the distinction may involve a systematic task analysis that would identify what components of the driving task are performed most automatically.

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