PROCESSING OF FLASHING DISPLAYS BY YOUNGER AND OLDER DRIVERS

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16. Abstract

This laboratory study was planned as a follow-up to an earlier study that investigated possible automatic processing of a flashing arrow (Schumann et al., 1995). In contrast to the previous experiment, only the arrow tail was flashing. The main research question was whether there is evidence for automatic processing of flashing, and if so, whether to use flashing as a means of assisting older drivers in extracting relevant information.

Two groups of subjects participated in this experiment: twelve older drivers with a mean age of 69, and twelve younger drivers with a mean age of 25. Subjects had to perform a two-alternative, forced-choice task, which involved responding to an arrow pointing either left or right. The response time was measured for different arrow presentation modes (steady vs. flashing tail) and distracter conditions (present or absent).

The results strongly suggest that flashing does not lead to an automatic processing of the stimulus information, and therefore flashing is not of any particular benefit for the elderly drivers. Although flashing of the arrow tail can enhance the salience of the arrow, the observer still must integrate features of the arrow in a controlled manner. Therefore, age-related slowing is expected, as can be seen in the results of this experiment.

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CONTENTS

INTRODUCTION

This experiment was designed as a follow-up to an earlier study that investigated the processing of flashing stimulus information by older adults (Schumann, Sivak, Flannagan, Aoki, & Traube, 1995). Although it has been demonstrated experimentally that a single abrupt stimulus onset is able to capture a subject's visual attention automatically (Jonides & Yantis, 1988), it remains to be shown whether multiple onsets of the same stimulus, which will be perceived as flashing, exhibit the same property of capturing attention automatically. The main research questions in our previous study were whether there was evidence for automatic processing of flashing information, and if so, whether to recommend the implementation of flashing as a means of assisting older drivers in extracting relevant information from onboard displays in a more efficient manner. The underlying motivation for the study was that deficits in age-related selective attention have been demonstrated to be attributable to age-related declines of controlled processing (McDowd & Birren, 1990). On the other hand, older adults were shown to be able to capitalize on automatic processes of visual information processing (Plude & Doussard-Roosesvelt, 1989).

However, the results of our previous experiment indicated that flashing, as it was implemented in that experiment, did not lead to an automatic attention-capturing, and consequently older adults did not benefit from the flashing information (Schumann et al., 1995). One possible explanation of that outcome was that, while flashing might have automatically attracted attention, the flashing of the complete arrow could have impeded the identification of the arrow direction and, therefore, could have slowed down the subject's response time. The present study was designed to evaluate this possibility.

Flashing of nondiagnostic stimulus features

The perceptual-encoding stage during information processing involves at least two subtasks:

(1) a selective attention task, during which the subject's attention has to be drawn to a specific object, and

(2) an identification task, during which the attributes of an object have to be identified.

To determine the direction of an arrow in a display, attention has to be drawn to the arrow and the arrow direction has to be identified. Clearly, the arrow head contains the relevant directional information, whereas the arrow tail does not contain such information. One way to attract the subject's attention, therefore, could be by flashing only the arrow-tail, while keeping the arrow head steady. In this manipulation only a nondiagnostic stimulus feature is flashed.

Age-related general slowing

While there is no evidence at this point that flashing will be able to attract a subject's attention automatically, the results of the previous experiment indicate that flashing does not eliminate the need for some controlled processing. If the flashing only produces a more salient stimulus, controlled processes are still necessary during the perceptual encoding stage (Plude & Doussard-Roosevelt, 1989). Under controlled processing an age-related slowing can be expected for older subjects.

For simple response-time tasks a longer latency, i.e., a slowing in processing time, is expected for older subjects compared to younger subjects. For simple psychomotor tasks, the latency of older adults (L_{older}) can be expressed as a linear relationship of the latency of younger adults' response times ($L_{younger}$) (Cerella, 1985, 1990):

$$L_{older} = m\,L_{younger} \tag{1}$$

Cerella (1985) found that older subjects (over 60 years) were slowed on the average by a factor of $m = 1.4$ with respect to younger subjects in their performance of simple psychomotor tasks.

Research questions

The present study was designed to investigate the effect of flashing information on the response times of younger and older adults. Specifically, the main research question concerned whether flashing could be either processed in a controlled or an automatic manner. Automaticity was tested in two ways:

(1) **Load-insensitivity criterion** (Jonides, Naveh-Benjamin & Palmer, 1985). According to this criterion, performance based on automatic processing should be insensitive to the presence of concurrent distracters in the visual display.

(2) **Flashing of distracters**. If flashing is processed automatically, a flashing distracter should distract the subject from the target. Responses during this condition should stay constant and subjects should not be able to develop a strategy to suppress the influence of a flashing distracter.

Further research questions concerned performance differences between younger and older adults. If flashing is processed automatically, older adults should perform similarly to younger subjects when presented with flashing stimuli. If, on the other hand, flashing has to be processed in a controlled way, age-related slowing should be expected for the older subjects in all experimental conditions to follow the linear relationship in Equation 1.

METHOD

Subjects

Twenty-four paid subjects, all licensed drivers, participated in the study. There were two age groups, each consisting of twelve subjects balanced by sex. Subjects were recruited from lists of potentially interested subjects maintained at UMTRI, as well as from a newspaper advertisement. The ages of subjects in the younger group ranged from 20 to 30 years (mean = 25.4; standard deviation = 3.3), and in the older group from 66 to 74 years (mean = 69.1; standard deviation = 2.6). None of the subjects participated in the earlier experiment (Schumann et al., 1995).

All subjects wore the same eyewear, if any, that they would normally wear when driving. Subjects with bifocals or trifocals were excluded from this experiment. Subjects' high-contrast visual acuity was assessed using a Titmus Vision Tester. The visual acuity ranged from 20/13 to 20/40 for the younger subjects and from 20/15 to 20/70 for the older subjects. (Only one subject had a visual acuity worse than 20/40, namely 20/70; however, the performance of this older subject was within the range of the other older subjects).

Tasks

Subjects had to perform a tracking task. This task, which was similar to steering a car down a winding road, was presented on a monitor. While the subjects were asked to focus on the tracking task, they also performed a two-alternative, forced-choice task. This task involved responding to the direction of an abruptly appearing arrow, which was presented on a separate monitor directly in front of the subject. The subjects were instructed to respond by pressing one of two response buttons.

Equipment

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

A 69-cm 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 just below the monitor for the tracking task (see Figure 2). After the eye position was adjusted correctly, subjects were asked to lean their heads backwards against a headrest.

Arrows for the forced-choice task were presented on a 38-cm monitor that was located 64 cm directly in front of the subject (see Figure 1).

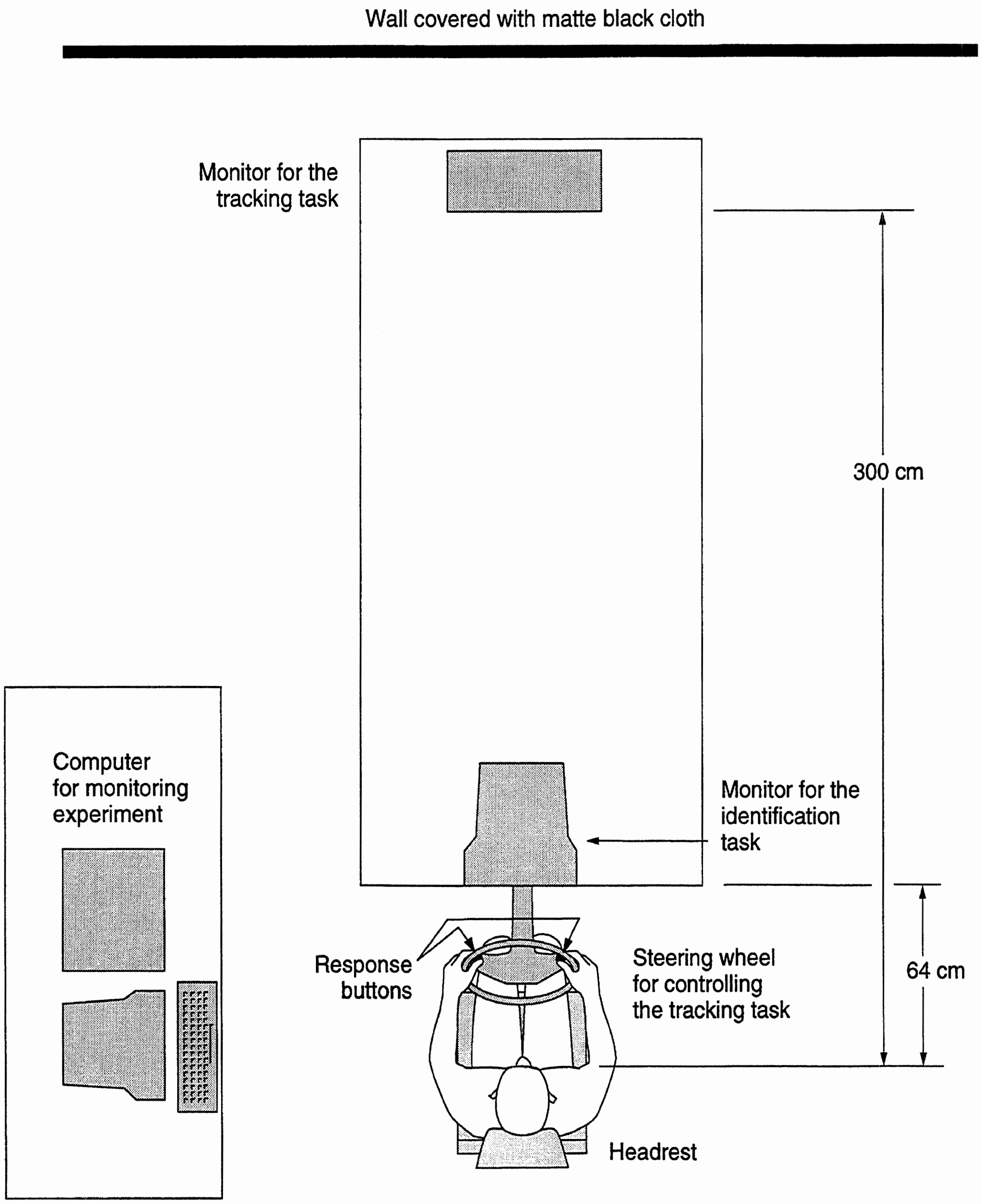

Figure 1. A schematic diagram of the experimental setup.

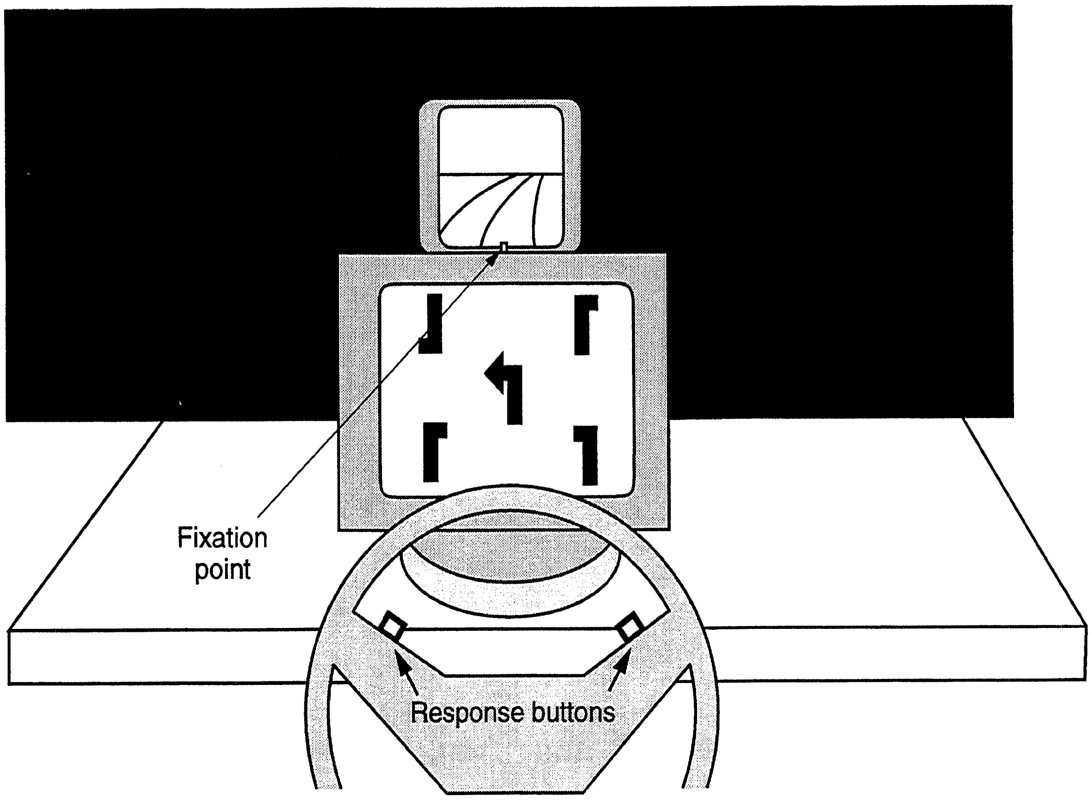

Figure 2. A schematic diagram of the subject's view, showing the monitor with one specific experimental condition of the identification task.

Overhead fluorescent lights were on throughout the experiment. In order to prevent the reflection of those lights from appearing on the tracking-task 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. The arrows were black on a white background. The arrow was presented in one of two presentation modes (Figure 3):

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

(2) flashing tail, in which the arrow tail was flashing at a rate of 6.25 Hz for 480 ms (80 ms on, 80 ms off; three complete cycles), and then remained steadily on for an additional 520 ms (the vertical refresh rate of the monitor was set to 67 Hz at a resolution of 640 x 480).

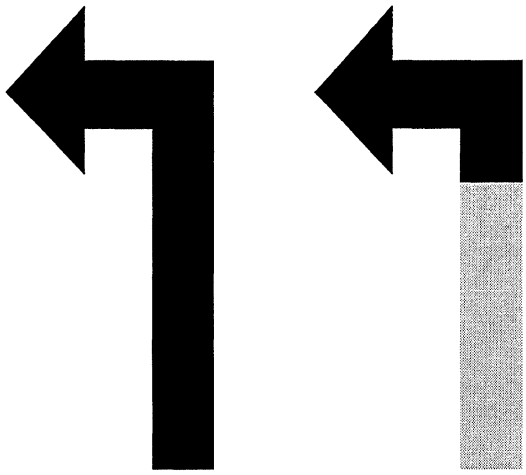

Figure 3. The two possible arrow stimuli pointing to the left: (1) steady (arrow tail: 50 mm x 8 mm, arrow head: 26 mm x 22 mm) or (2) flashing tail (flashing tail 35 mm, the gray part of the flashing tail was alternately black or completely absent during the flashing period).

In one of the experimental conditions the arrow was presented together with a set of four similar distracters during the entire one-second presentation time (see Figure 4). Each of the four distracters was always chosen randomly from the complete distracter set. 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).

One experimental condition consisted of a set of four distracters with one of the four distracters randomly chosen to flash for the full presentation time (1 sec) at the same rate as the flashing-tail rate (6.25 Hz).

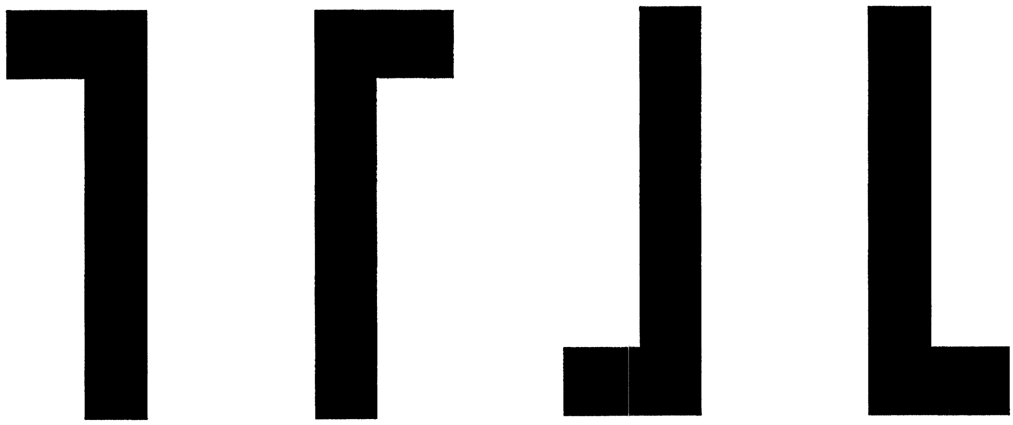

Figure 4. The four possible distracters (tail: 50 mm x 8 mm, side part: 10 mm x 8 mm).

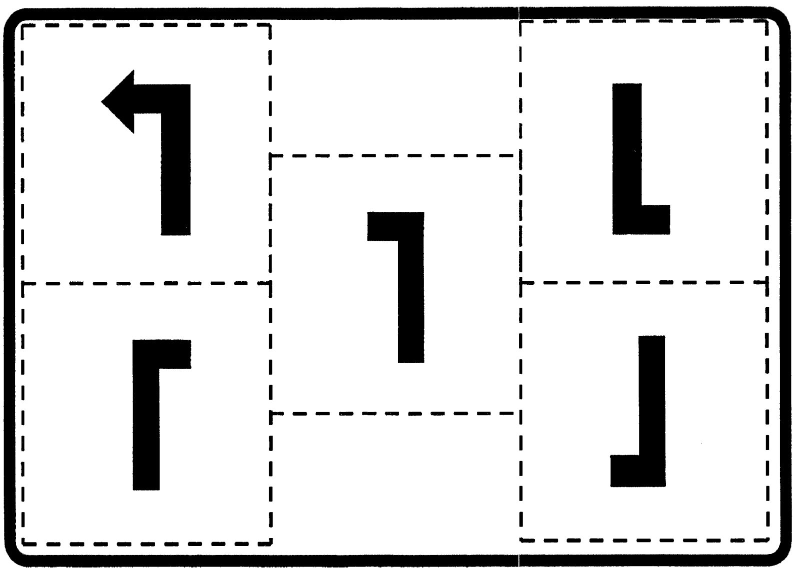

Figure 5. Example of an arrow stimulus presented with distracters (scaled down). The dashed lines (not present in the actual display) separate the five possible screen positions.

Experimental design

The following independent variables were factorially combined:

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

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

(3) Distracters, a within-subjects variable with three levels (absent, present, present with one flashing).

(4) Block sequence, a within-subjects variable with two levels (first, second).

Block sequence was introduced as an independent variable to evaluate any changes in subjects' strategy in dealing with the target stimuli in the different experimental conditions.

The three distracter conditions were presented in different blocks of trials, with the order of the distracter levels balanced across subject-age groups. For each distracter block, both block sequences were presented in succession.

Each of the six experimental blocks consisted of 20 trials, and the order of those 20 trials was randomized. Each of two levels of presentation mode 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).

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.

During the entire block, subjects had to keep their eyes on a small fixation point that was located at the bottom of the distant monitor. They were asked not to turn their head or eyes towards the monitor where the arrows were presented.

At the beginning of the experiment three practice blocks were given for each subject. The first block was made up of 10 trials in which subjects had only to respond to the arrows. This first practice block was made up of trials of the same distracter condition as the first experimental block. During the second practice block, subjects were allowed to practice just the tracking task until they felt comfortable with it.

In the third practice block, they received 10 trials in which they had to respond to the arrows and to perform the tracking task at the same time. It was stressed that during all trials they should focus on the white fixation point located centrally below the television monitor. After that practice block, each subject had to perform six experimental blocks. Each time the distracter block conditions changed (i.e., before the third and the fifth experimental block), subjects received another practice block of 10 trials with the corresponding distracter condition and the tracking task.

The dependent variable was response time, measured from the time 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 four lengths of intertrial intervals: 5, 7, 9, and 11 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.

RESULTS

Overview

The data were first analyzed for false responses and missed trials. Data from correct trials were then combined for the two arrow directions and the five different screen positions, and the average response times for each of the experimental conditions distinguished by presentation mode, distracters, and block sequence were calculated for each subject.

Analyses of variance (4-factor ANOVA, mixed design) were then used to examine the effects of age, presentation mode, distracters, and block sequence on the subjects' performance. Separate analyses of variance were performed for the percentage of incorrect responses (i.e., incorrect responses and missed trials) and reaction time. (Preliminary analyses of variance that included sex as an independent, between-subjects variable showed no significant effects of sex for either dependent variable.)

Performance measure: Incorrect responses

For the entire group of 24 subjects there were only 21 missed trials (0.73%). Because there were so few missed trials, they were combined with the incorrect responses. There were 217 incorrect responses (7.54%), for a total of 238 (8.26%) incorrect or missing responses. In every block of 20 trials, each subject had at least one correct response to the steady or the flashing-tail arrow for each arrow direction. (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.)

A 4-factor analysis of variance on the incorrect responses resulted in a significant main effect of presentation mode of the arrow, $F(1,22) = 9.79$, $p = .005$, and a significant main effect of distracters, $F(2,44) = 16.70$, $p < .0001$. Subjects had more incorrect responses when they had to respond to a steady arrow (see Figure 7), and when distracters were present together with an arrow in the display (see Figure 8). Although older subjects had more incorrect responses than younger subjects (9.7% vs. 6.9%), age was not statistically significant. Block sequence also was not significant.

A post-hoc analysis revealed that the only significant differences for the distracter conditions were those between the distracters-absent and distracters-present conditions, and between the distracters-absent and one-flashing conditions, but no differences between the two distracters-present conditions, HSD (3,44) = 4.8%, $\alpha = .05$.

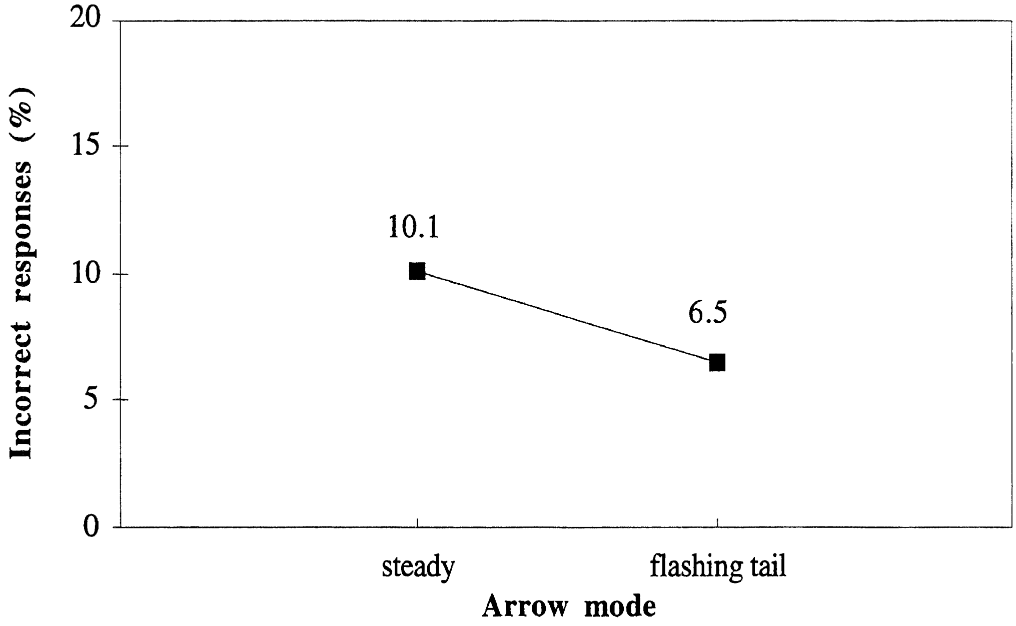

Figure 7. Percentage of incorrect responses by presentation mode of the arrow.

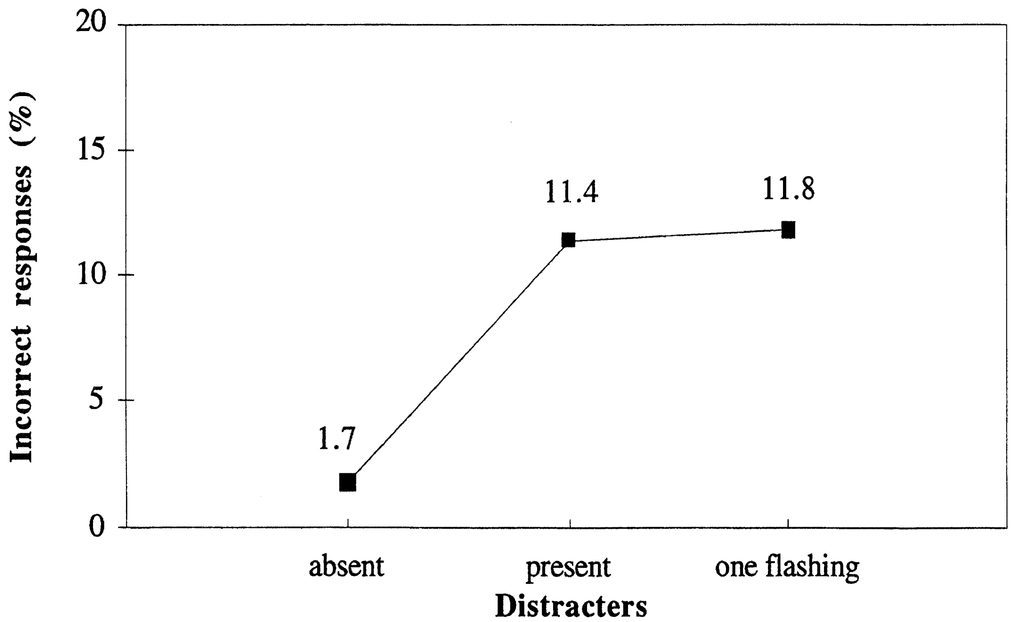

Figure 8. Percentage of incorrect responses by distracter condition.

There was also a significant presentation mode by distracters interaction, $F(2,44) = 5.69, p = .006$, which is depicted in Figure 9. A post-hoc analysis revealed that subjects had significantly fewer incorrect responses to the flashing-tail arrow when it was presented together with distracters, independent of the type of distracters, HSD (6,44) = 4.5%, $\alpha = .05$.

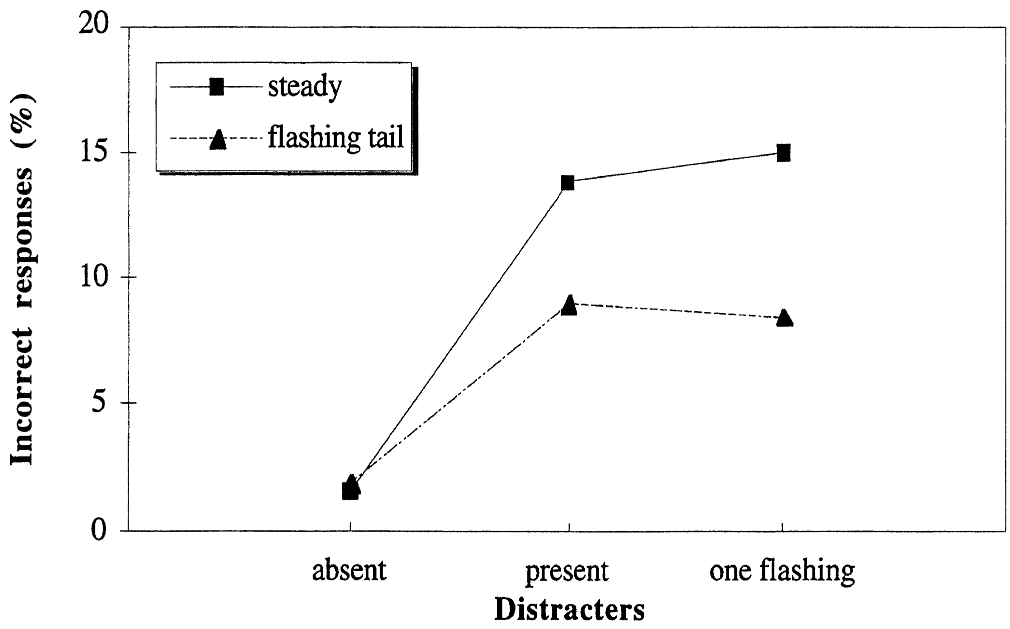

Figure 9. Percentage of incorrect responses by presentation mode of the arrow and distracter conditions.

These results indicate the following:

(1) a flashing-tail arrow is more salient than a steady arrow when presented together with distracters; and

(2) a flashing distracter does not additionally distract the subjects.

Performance measure: Reaction time

In conditions in which there were no false responses or missed trials, 10 reaction times (5 screen positions x 2 arrow directions) were averaged for each independent factor level. In conditions in which there were incorrect responses or missed trials, the remaining correct trials were averaged.

The 4-factor analysis of variance on the mean reaction times resulted in significant main effects of age, $F(1,22) = 18.99$, $p < .0003$, presentation mode of the arrow, $F(1,22) = 5.92$, $p = .024$, and distracters, $F(2,44) = 34.24$, $p < .0001$. There was also a significant block sequence x distracters interaction, $F(2,44) = 3.34$, $p = .05$.

Older subjects needed more time to respond to the arrows, and all subjects responded faster to a flashing-tail arrow (see Figure 10).

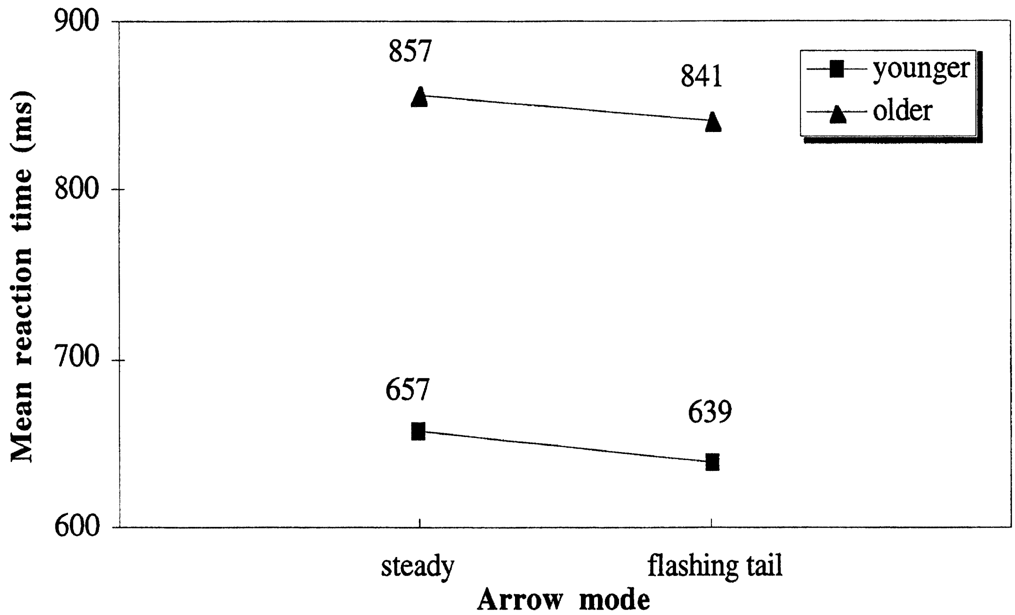

Figure 10. Mean reaction time by presentation mode of the arrow and age group.

Subjects also needed more time to respond to an arrow when the arrow was presented together with distracters (see Figure 11). A post-hoc analysis revealed that the only significant differences for the distracter conditions were those between the distracters-absent and distracters-present conditions, and between the distracters-absent and one-flashing distracter condition, but with no difference between the two distracters-present conditions, HSD (3,44) = 48.3 ms, $\alpha = .05$.

The block sequence by distracters interaction is depicted in Figure 12.

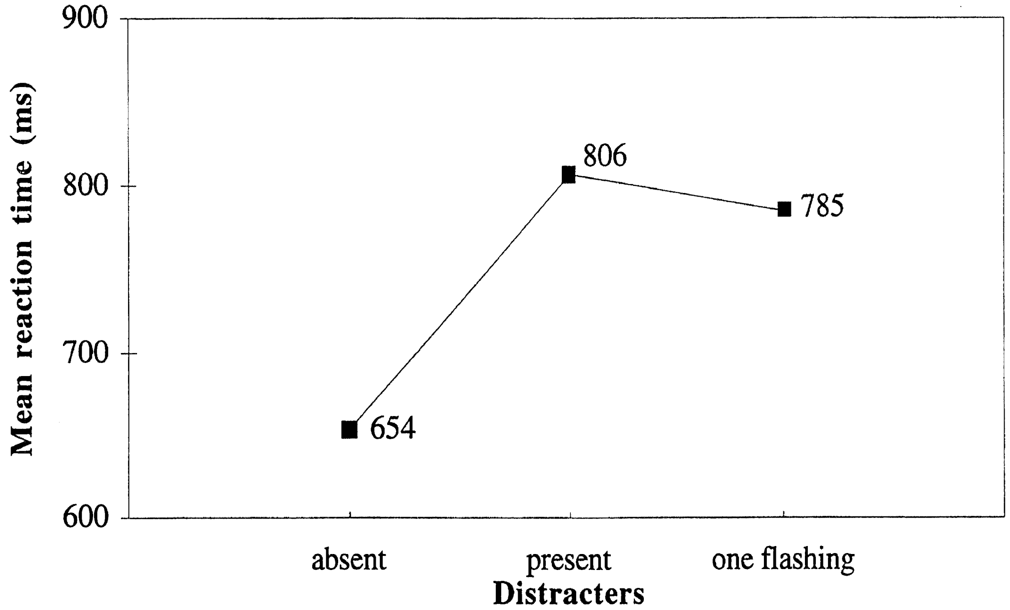

Figure 11. Mean reaction time by distracter conditions.

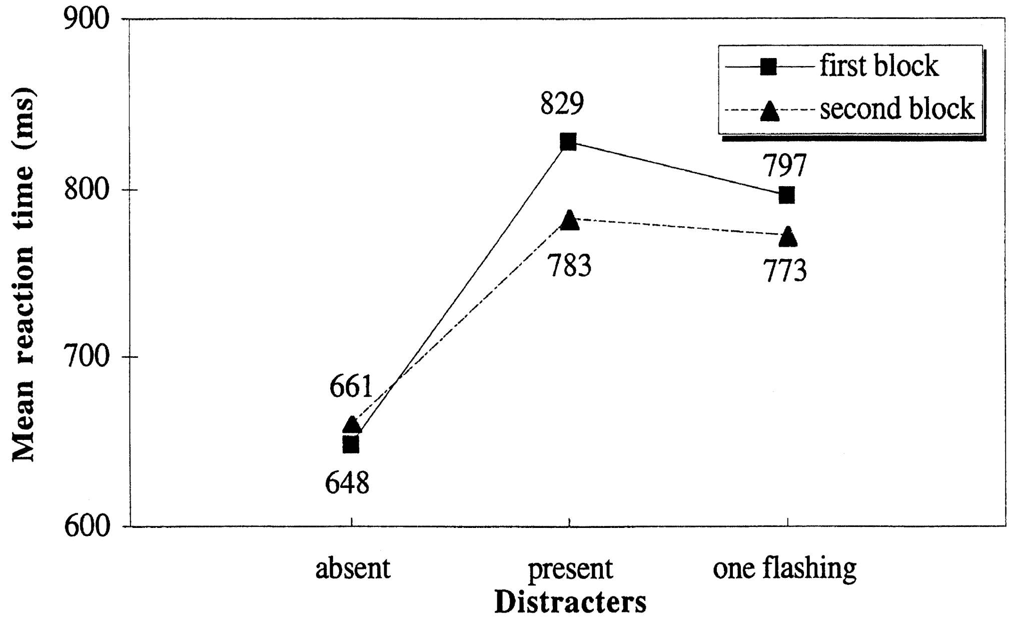

Figure 12. Mean reaction time by trial order and distracter conditions.

However, the reaction-time data provided no evidence that flashing was processed automatically (there was no significant presentation mode by distracters interaction). Neither did the reaction-time data support the load-insensitivity criterion (expected zero-slope for flashing-tail arrow), nor did the flashing distracter slow down the subjects' responses (see Figure 13). Figure 13 clearly indicates that flashing was not processed in an automatic manner.

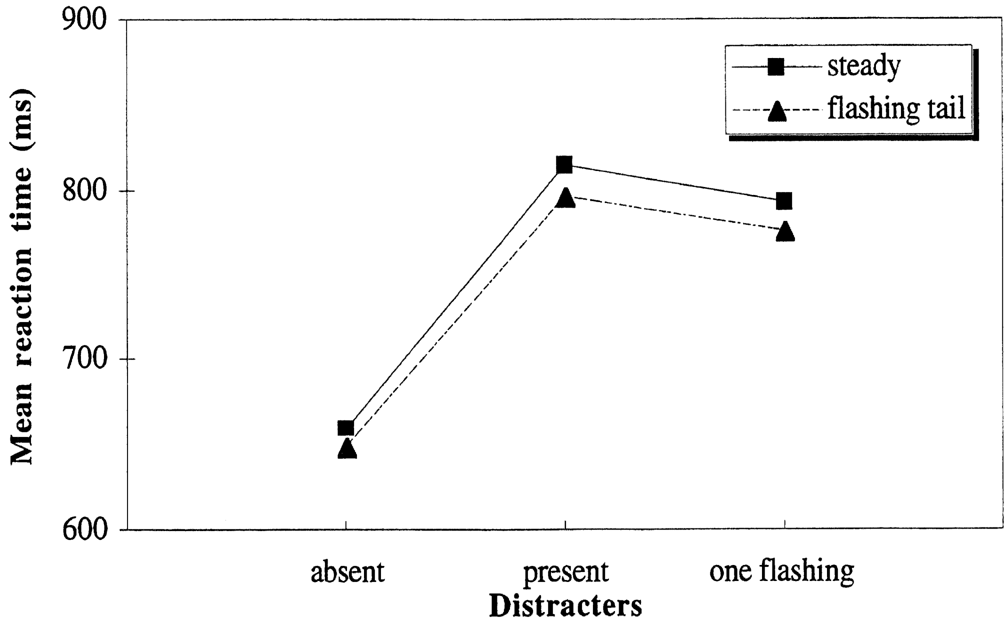

Figure 13. Mean reaction time by presentation mode of the arrow and distracter conditions.

If the identification task requires controlled processing, age-related general slowing should be expected. Table 1 lists the mean reaction times for the significant experimental conditions for both age groups and the calculated slowing factor m (see Equation 1) from these data.

Table 1. Mean reaction times for significant experimental conditions by age groups and the calculated slowing factor.

Condition	Younger (ms)	Older (ms)	Slowing factor m
steady arrow	656.8	856.8	1.31
flashing-tail arrow	638.5	841.4	1.32
no distracters	557.0	751.8	1.35
with distracters	684.8	927.1	1.35
one flashing distracter	701.2	868.3	1.24

Interestingly, the slowing factors in Table 1 are close to the reported slowing factor by Cerella (1985) for data on group mean reaction times for simple tasks ($m = 1.4$), and they support age-related general slowing for this type of task.

Although there was no large advantage of the flashing-tail arrow during the distracter conditions (see Figure 13), there seems to be some benefit of the flashing-tail arrow when additional information is present, as can be seen if one takes into account the significantly reduced error rate with the flashing-tail distracter (see Figure 9).

Figure 14 compares the results of this experiment to those of our previous experiment (Schumann et al., 1995).

Longer reaction times to the steady arrow when presented together with distracters in the first experiment can be explained by different experimental procedures in the two experiments. In this experiment the three distracter conditions were blocked (and the subjects, therefore, knew in advance that an arrow always would be presented together with distracters). However, the task demand in the earlier experiment was higher, because arrows were randomly presented either with or without distracters. This could have had a negative influence in the most difficult condition, which involved detecting a steady arrow presented with distracters.

On the other hand, the two different flashing arrow conditions (flashing only the tail of the arrow vs. flashing the complete arrow) led to similar results, which strengthens the assertion that flashing in both experiments was processed in a controlled way. The suspicion in the first experiment that flashing of the complete arrow might have masked an effect of automaticity due to a slowing of the information processing during the identification stage is not supported by the results of this experiment.

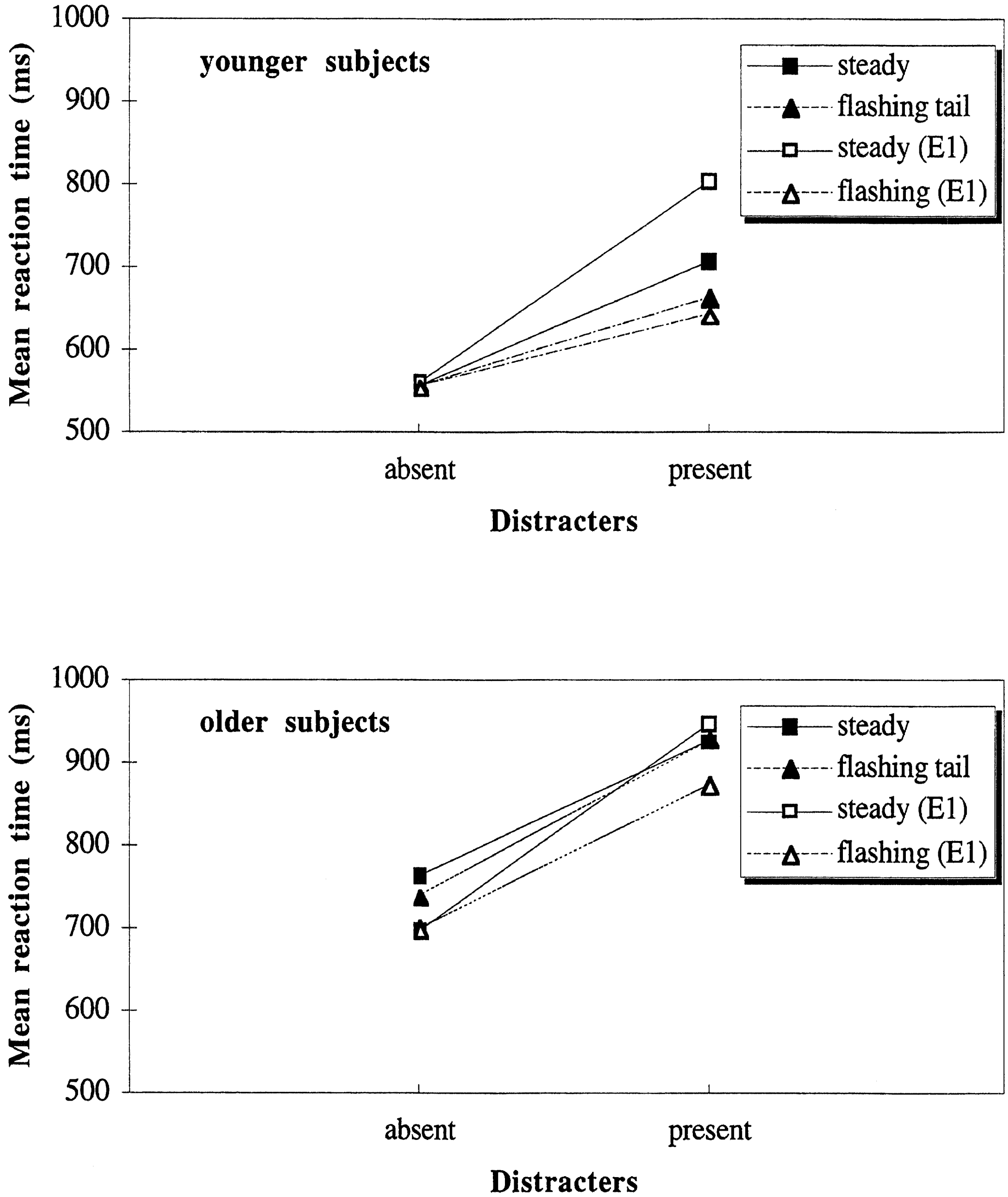

Figure 14. Mean reaction time for comparable experimental conditions of this experiment and an earlier experiment (E1, Schumann et al., 1995) for younger subjects (top panel) and older subjects (bottom panel).

DISCUSSION

The results of this study and the previous study (Schumann et al., 1995) strongly suggest that flashing, as it was implemented in these experiments, does not lead to an automatic processing of the stimulus information. Consequently, flashing does not appear to be of any particular benefit to the elderly drivers.

Although there seems to be some evidence that flashing increases the salience of an object and therefore facilitates the detection of that object in a display (see Figure 14), this increased salience is not accomplished in an automatic way, because subjects at the same time were able to block out a flashing distracter without any performance penalty (see Figures 11 and 13).

The failure to demonstrate automatic attentional capture by flashing seems to suggest that multiple abrupt onsets, presented in the context of single abrupt onsets, do not capture attention in the way that single abrupt onsets do in the context of stimuli presented without abrupt onsets. However, a definitive statement of how flashing in general is processed cannot be made from this experiment. That would require a systematic manipulation of multiple onsets, with respect to the abruptness of the onsets and the frequency of the flashing.

As the results of the previous experiment demonstrated, the complete flashing of the arrow did not lead to automatic processing of the arrow (Schumann et al., 1995). Flashing, therefore, may enhance performance by increasing the salience of the target rather than by causing an automatic shift of attention. The results of this experiment also support this interpretation for flashing of the arrow tail (see Figure 13). The comparisons in Figure 14 suggest that flashing of the complete arrow is at least as effective as flashing of only the arrow tail in increasing the salience of the arrow.

What do these results mean with regard to the performance of older drivers in identification tasks? Because the identification task has to be performed in a controlled manner, age-related slowing has to be expected, as can be seen in the results of this experiment (see Table 1). The best strategy in any display design, therefore, should be to make a target as salient as possible in order to compensate for expected difficulties of older people in suppressing irrelevant information during controlled processing. Possible candidates for obtaining maximum salience can be a distinctive form, color, flashing, or even a combination of these features. However, one should always be aware that, because controlled processing is involved, older drivers will need significantly more time than younger subjects for completing the same task.

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