AGE RELATED DECREMENTS IN STEERING CONTROL: THE EFFECTS OF LANDMARK AND OPTICAL FLOW INFORMATION

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Summary: This study examined age related decrements in the use of optical flow and landmark information for the control of steering. Older and younger drivers viewed computer generated displays simulating vehicle motion through a random dot ground plane scene. The horizontal position of the driver was perturbed according a sum of sines function and the driver had to keep steering straight (resembling the task of steering a car on a gusty day). On half the trials, landmark information was presented by color coding one of the dots on the ground plane. Overall, older drivers showed greater steering error magnitude (RMS error) than younger drivers. Unlike the younger drivers, the older drivers showed no reduction in steering errors when landmark information was present. These results suggest that older drivers are more reliant on optical flow information for controlling a vehicle and have a reduced ability to use alternative sources of information, such as landmarks, for steering control.

INTRODUCTION

An important perceptual task during driving is the ability to use visual information to steer. Failure to accurately detect changes in the path of motion and make corrections to the vehicle's path of motion could have serious consequences for driver safety. One source of information that has been extensively studied for the perception and control of steering is optical flow—the perspective transformation of the optic array (Gibson, 1966; 1979). Research on optical flow has demonstrated the usefulness of this information for the perception of heading (Warren, Morris, & Kalish, 1988; Warren, Mestre, Blackwell & Morris, 1991), the perception of self-motion (Andersen & Braunstein, 1985), and the perception of egospeed (Larish & Flach, 1990). A critical assumption of optical flow research is that the spatial and temporal characteristics of the stimuli result in a perception of apparent motion.

Recent research (Hahn, Andersen, & Saidpour, 2003) has considered a new source of information for the perception and control of locomotion based on landmarks within the scene. Hahn et al. noted that optical flow information, in isolation, does not provide reference information for steering control. As a result, drivers may rely on landmarks to provide reference information regarding the path of motion. To examine this issue they presented subjects with two consecutive frames depicting observer motion through the scene and examined interstimulus interval (ISI) durations that would or would not result in a perception of apparent motion. The results indicated that observers could determine the path of motion under conditions that did not result in apparent motion, suggesting the subjects used scene-based information to perceive the path of locomotion. In a subsequent study, Andersen and Enriquez (2005) examined whether scene-based information was used in controlling the path of locomotion or steering. Subjects viewed random dot displays simulating forward motion through a 3D scene. The horizontal position of the observer's viewpoint was perturbed according to a sum of sines function. The subject's task was to steer the path of motion to maintain a straight path. This task has been extensively used to study the control of locomotion in driving (Hildreth, Beusmans, Boer, & Royden, 2000; Andersen & Saidpour, 1999; Beall and loomis, 1996). Results showed improved steering performance when landmark information (vertical bars) was presented, indicating that observers use scene-based information for steering control.

Previous research has demonstrated age-related decrements in the perception of motion and in the use of optical flow information for the perception of 3D shape (Andersen and Atchley, 1995). The goal of the present study was to examine age-related differences in the use of optical flow and scene-based information for steering control. Similar to the Andersen and Enriquez study, drivers were presented with computer generated displays simulating forward vehicle motion through a 3D scene of random dots on a ground plane. The horizontal position of the vehicle was perturbed according to a sum of sines function, and drivers were asked to steer the vehicle to maintain the initial path of motion. On half of the trials, landmark information was presented by color coding a subset of the dots.

Two hypotheses concerning age-related differences were tested. Previous research has shown that the use of optical flow information for perceiving the path of observer motion requires the spatial integration of velocity information. Recently, we have found that older observers had a decreased ability to spatially integrate velocity information to perceive motion-defined edge boundaries. We hypothesize that older drivers, as compared to younger drivers, will show a decreased sensitivity to spatially integrated velocity information for steering control from optical flow. To test this spatial integration hypothesis, we varied the number of dots in the display producing lesser or greater spatial separation of the velocity information. If the spatial integration hypothesis is correct, then age-related differences in steering performance should be more pronounced at low as compared to high dot densities.

The second hypothesis concerns the use of landmark information. To use landmarks for steering control, a driver must encode the spatial location of landmark positions and use this positional information as reference information to maintain the initial path of motion. Older drivers may have difficulty encoding and using landmark position information, leading to less benefit for steering control when landmark information is present. To examine this landmark position hypothesis we presented landmark information on half of the trials. If older drivers, as compared to younger drivers, have greater difficulty in using this information then we predict that younger drivers, as compared to older drivers, will have greater accuracy in steering control when landmark information is present.

EXPERIMENT

Methods

Drivers. The drivers were 31 older (mean age of 71.0) and 16 younger (mean age of 28.3) individuals. All drivers were screened for basic cognitive and perceptual ability. All drivers had normal or corrected-to-normal vision and were naïve to the purpose of the experiment.

Design. The independent variables were number of dots in the optic flow field (25 or 325), landmark condition (presence or absence), frequency of the horizontal perturbation (0.83, 0.216 and 0.161 Hz), and age group (younger and older). Age group was treated as a between-subjects variable. All other variables were run as within-subject variables.

Apparatus. The displays were presented on a Dell PC computer system. The visual angle of the displays was 47 deg by 26 deg, with the refresh rate at 60 Hz and the resolution at 1024 by 768. Display update was 50 Hz. A Thrustmaster Formula T2 steering system was used for steering control. Angular displacement of the steering wheel was linearly related to the horizontal displacement in the simulation. Drivers viewed the displays binocularly at a distance of approximately 40 cm from the screen.

Stimuli. The displays simulated driving through a 3D array of dots located on a ground plane. The simulated speed was 45 mph. The dimensions of the space were 400m (width) by 150m (depth), with the simulated eye position of the driver at 1.6 m above the ground. The horizontal positions of the dots pattern was perturbed according to a sum of 3 prime sine-wave frequencies forcing function. Amplitude of the frequencies was selected to provide equal energy in the fourier domain. The three frequencies used were 0.083, 0.216 and 0.161 Hz. The amplitudes for these frequencies were 17.51, 9.02, and 6.74 units, respectively. The first two phases of the sine-wave function were randomized across trials. The last phase was determined such that the output of the sum of 3 sine-wave functions was 0 at the beginning of each trial. The scene consisted either of 25 or 325 randomly positioned white dots on a black background to form the ground plane. For displays without landmark information, all the dots were achromatic. On half the trials, landmark information was presented by providing color to five dots within the flow field. The dots were randomly positioned at the beginning of the display, and then the viewpoint moved at a simulated speed of 45 mph. Any dots that moved out of view port would be randomly repositioned at the far end of the ground plane, except that the red dots would just reenter the scene from the far end. The display duration of each trial was 120 seconds.

Procedure. Drivers were to maintain a fixed heading direction relative to the moving dots. Drivers were presented with flow fields simulating a horizontal displacement specified by a single sine wave function (0.7091 Hz; amplitude of 3) as an example of the task. They were told that the display was comparable to driving down a straight roadway with lateral wind gusts perturbing their position on the roadway. In addition, they were told that their task was to correct their position on the roadway such that they maintained driving along a straight path.

Drivers were presented with 2 displays in which forward motion was perturbed by single sine waves to illustrate the displays. Once the subjects understood the task, they were given two 60-

sec practice trials in which they responded to the single sine wave forcing function to familiarize the subject with the task and the control dynamics.

Following completion of the practice trials, subjects were presented with four replications of each condition for a total of 8 trials. The order of the landmark condition and dot numerosity was randomized for each subject.

RMS and Coherency Results. Steering performance was assessed by calculating RMS (root means square) tracking error for each driver on each trial in each condition. In addition, control coherency (the squared correlation between the input and response at a particular frequency) was derived.

The average results for RMS error are shown in Figure 1. An ANOVA (analysis of variance) revealed that younger drivers had significantly less tracking error than older drivers (F (1, 46) = 8.6, p<.05). The average RMS error for younger and older drivers was 9.9 and 12.4, respectively. Both older and younger drivers had less tracking error with a greater number of dots in the flow field (F (1, 46) = 52.4, p<.05).

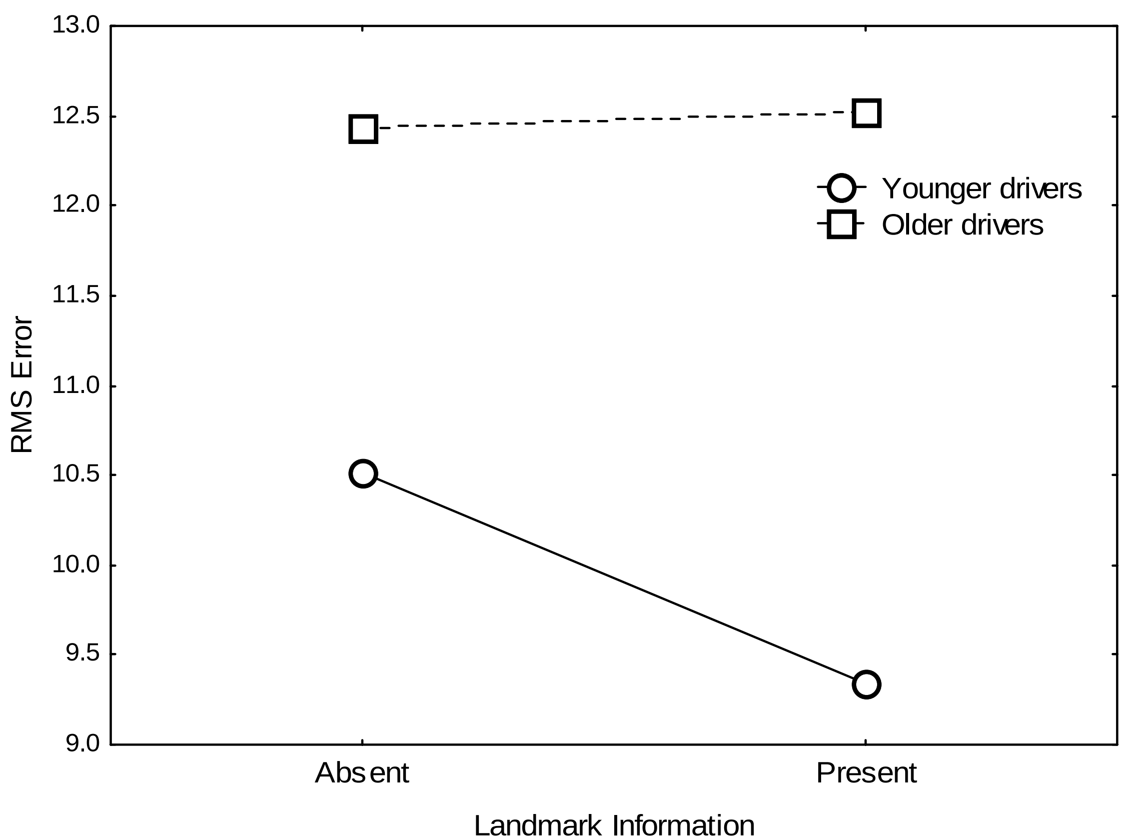

Figure 1. Interaction of age group and landmark information for RMS error

The two-way interaction of age group and landmark condition was significant, F (1, 46) = 4.6, p<.05. Younger drivers had less tracking error when landmark information was present. In contrast, older drivers showed no effect of the presence or absence of landmark information.

The average squared coherency value (a measure of variance accounted in tracking performance for each frequency) was calculated for each driver in each condition and analyzed in a two (dot numerosity) by two (landmark) by three (frequency) ANOVA. The main effect of dot numerosity was significant, $F(1,46) = 11.2$, $p<.05$, indicating greater squared coherency for the 325 dot condition (mean squared coherency of 0.91) as compared to the 25 dot condition (mean squared coherency of 0.84). The main effect of frequency was significant, $F(2, 92) = 10.6$, $p<.05$ indicating greater squared coherency with a decrease in frequency. The two-way interaction between dot numerosity and landmarks was significant, $F(1, 46) = 5.9$, $p<.05$ as well as the three-way interaction of age group, dot numerosity and landmarks, $F(1, 46) = 5.8$, $p<.05$.

The three way interaction is shown in Figure 2. According to this result, younger drivers showed little effect of the landmark condition for the 325 dot numerosity condition. However, younger drivers had a significant increase in squared coherency for the 25 dot numerosity condition when

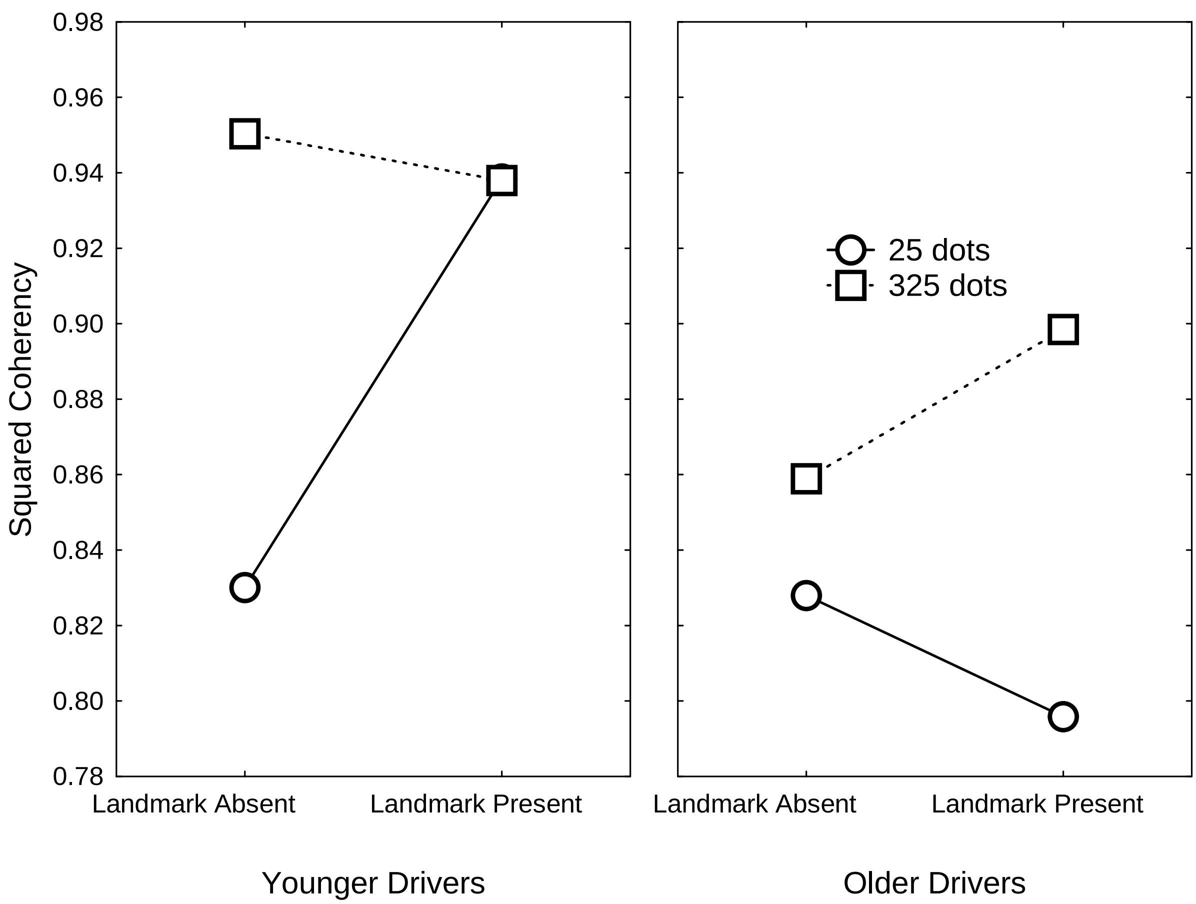

Figure 2. Three way interaction of dot numerosity, landmark condition and age group.

landmark information was present. Older drivers showed a different pattern of results. For the 325 dot numerosity condition, the presence of landmark information increased squared coherency. However, for the 25 dot numerosity condition, older drivers showed a decrease in squared coherency with landmark information. These results indicate two important points. First, that the presence of landmark information is useful for younger drivers when optical flow information is reduced. Second, that older drivers show a trend towards reduced performance when landmark information is present and optical flow information is reduced.

Discussion

Overall, the results of the present study suggest that greater accuracy and less steering control error occurred for younger as compared to older drivers. Both groups showed an improvement in driving performance with an increase in optical flow information. However, younger drivers, as compared to older drivers, were more efficient at using optical flow information and were able to use landmark information to improve steering control. These findings indicate that older drivers may be more reliant on optical flow information for controlling a vehicle and may have a reduced ability to use alternative sources of information for steering control. The decreased reliance of landmark information for older drivers, when optical flow information is reduced, may be the result of attention. Previous research (Cassavaugh, Kramer, and Irwin, 2003) found that older subjects had greater difficulty than younger subjects in ignoring distractor items when scanning a display, presumably a result of difficulty in disengaging attention to irrelevant information. In the present study, older drivers may, under reduced optical flow conditions (such as during nighttime driving or when fog is present), focus their attention on the landmarks and have difficulty disengaging their attention from the landmarks to scan other parts of the scene. An important issue for future research will be to examine age-related differences in attention under the visibility of optical flow is reduced.

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