Visual inspections made by young and elderly drivers before lane changing

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Abstract

Lane changing is a complex driving maneuver that could challenge elderly drivers. The aim of this study was to evaluate eye glances of young and elderly active drivers when engaging lane change maneuvers. Young (21-31 years) and older (65-75 years) active drivers drove through a continuous simulated environment (STISIM, v2.0). The scenario included 16 events where the driver needed to glance at three regions of interest (ROI): 1) the rear-view mirror, 2) the left-side mirror, and 3) the left blind spot to ensure secure lane change. The lane change maneuvers were necessary to avoid a static object that was partially or completely blocking the lane or for overtaking a slower moving vehicle. Compared with younger drivers, older drivers showed a reduced frequency of glances toward the left-side mirror and the blind spot. While the older drivers showed a constant frequency of glances across the two types of driving maneuvers (i.e., avoiding a static object and overtaking a slower vehicle), the younger drivers generally showed a higher frequency of glances and this frequency increased when overtaking a slower vehicle. A better knowledge of the elderly drivers' behavior could be beneficial in identifying at-risk behaviors and to retrain older drivers to adopt safer behaviors.

Keywords – aging, visual inspection, head movements, lane changing

1. Introduction

Driving is important for a large percentage of the elderly population. Unfortunately, difficult driving contexts such as negotiating intersections and overtaking maneuvers [1] [2] often challenge older drivers. These complex maneuvers need coordination between head and eye movements to bring the image of surrounding objects (most often neighbouring vehicles) to the fovea (where they are best perceived and often processed at the cognitive level) [3]. For instance, before changing lanes the driver needs to check the rear-view and left-side mirrors and the blind spots using appropriate eye-head movements. These perceptual-motor processes are continual and make up the basis for complex decision making yielding to secure lane changing.

There are several on-the-road and simulator studies that have looked at eye fixation patterns. Perhaps one of the most widely cited study on this topic is that of Mourant and Rockwell [4].

They reported that, compared with more experienced drivers, novice drivers sampled their rear-view and left-side mirrors less often and concentrated their visual search on a smaller area that was closer to the vehicle. Underwood and colleagues [5] [6] [7] [8] and others [9] recently expanded on this work with a series of studies comparing novice and more experimented drivers. Without going into the details of these experiments, it can be said that experienced drivers select visual search strategies according to the complexity of the driving context and show a greater variety of scanning behaviors than novice drivers. There are also a series of studies looking at the specific eye-head movements before a lane change. Robinson et al. [10] reported that the first search is toward the left-side mirror in 70-80% of the lane changes and that the number of glances increases with an increased traffic density. More recently, Wierwille and collaborators conducted an extensive analysis of on-the-road glances during the 3-s period preceding lane changes [11] [12]. They reported glance durations of 2.4 s (on this issue, see also [13]) with 46% of the left lane changes having a glance to the rear-view mirror, 53% to the left-side mirror and only 30% to the left blind spot. These values were all greater than for straight-ahead driving for which most of the glances were directed toward the rear-view mirror or the instrument cluster (23% and 25%, respectively) with almost no glances toward the left-side mirror (10%) and the left blind spot (3%).

Surprisingly, there is a scarcity of information about the effect of aging on eye-head movements during lane change maneuvers. There are reports, however, suggesting that elderly drivers may exhibit a perceptual narrowing [14]. In addition, older drivers are less accurate, especially with high-clutter scenes, and slower to identify the information available in a static scene [15] [16]. Such behaviors could put them at risk when changing lanes.

The aim of the present study was to test the hypothesis that, before a left lane change, older drivers visually inspect three regions of interest (ROI; rear-view mirror, left-side mirror, and blind spot) less frequently than young and active drivers.

2. Methods

2.1. Subjects

Twelve young (age range = 20-24 years) and eleven older active drivers (age range = 66-75 years) took part in the study. Upon their arrival in the laboratory, each participant was briefed on the requirements of the experiment and all read and signed an informed consent declaration conformed to Laval University Institutional Review Board. Then, subjects were given a general verbal questionnaire, including items on driving (years of driving experience, frequency of driving and average km/year, presence of accident within the last few years) and general health condition (neurological and musculoskeletal problems, use of medication). Simple clinical tests (Mini Mental State Examination, MMSE [17], Snellen visual acuity, Melbourne Edge test [18], ankle proprioception acuity, lower limb touch thresholds measured with a Semmes-Weinstein pressure aesthesiometer) were used to screen for impairments that might affect driving and cognition.

2.2. Apparatus

The experiment was conducted with a fixed-based open-cab simulator powered by STISIM Drive 2.0 [19]. The simulator projects images on a flat wall (1.45 m high x 2.0 m wide) located 2.2 m from the steering wheel using a liquid crystal display (LCD) projector (Hitachi CP-X275). It displays a 40° horizontal by 30° vertical field-of-view with the center of the screen located at eye-level through the midline of the subject. To simulate real-driving conditions, the left-side mirror and a panel positioned in the left blind spot are instrumented with a green and a red light-emitting diode (LED). The green LEDs inform the driver that a lane change is possible, whereas the red LEDs inform the driver to continue driving until green LEDs become active. The information displayed by the LEDs is in correspondence with the information displayed in the rear-view mirror. To capture visual information during lane changes, three IEEE-1394 video cameras (Prosilica CV-640) were mounted on the cab facing the subject and zoomed to fully capture head and eye movements. None of the cameras interfered with the visual field. To maintain ideal lighting conditions for the simulation, infrared lighting was provided with three illuminators (Cantronic 30 deg with 850 nm wave length). Head movements (panning) were recorded with an electromagnetic system (Flock of Birds) fixed on a small headband. A fourth camera (Point Grey Research, Flea BW) captured the scenario displayed on the screen. Data acquisition was time locked with hardware signals and collected on three different computers (all digital video (DV) signals collected at 30 Hz with custom software developed using Unibrain Fire-API SDK; head movements recorded at 60 Hz using ASL software; car and steering responses recorded with STISIM software). Data were collected for specific events during an overall scenario (see below). A digital signal based on the position of the car within the scenario triggered all data acquisition systems for a constant duration (about 40 s).

2.3. Procedures

Subjects were first familiarized with the simulator [20] before driving through an uninterrupted driving scenario (26.4-km). Briefly, subjects were informed that the simulator could make them feel uncomfortable and they were specifically instructed to inform the experimenter if this happened. They were told the experiment would stop immediately without any prejudice for them. To prevent uncomfortable sensations, the temperature within the room was maintained at about 17 °C with proper ventilation using a ceiling vent positioned just above the driver. A 12-km practice scenario (with less graphical information than the experimental scenario) served the purpose of familiarizing subjects with the simulator and the general feel of the pedals and steering. A 5-min rest between the practice and the experimental run was provided. A visual analog scale (VAS: 0 being no discomfort at all and 10 being mild nausea) was used to document simulator discomfort. Measures were taken before the practice run, after the practice run, half-way through the experimental run and the end of the experimental run. In the present study, all but 2 elderly subjects reported being comfortable after the practice run. These two subjects scored respectively 5.9 and 9.5 on the VAS and stopped the practice run after 3 km and 10 km, respectively. Data for these two subjects are not reported herein. The mean VAS at the end of the experiment was 0.58 (SD = 1.24) and 2.95 (SD = 3.63) for the young and elderly subjects, respectively.

The scenario included 16 events for which the driver needed to look at the rear-view and left-side mirrors and at the left blind spot before a lane change. The lane changing maneuvers were necessary for 1) avoiding a static object partially or completely blocking the lane (e.g., a motionless car parked halfway into the shoulder, n=7), or 2) overtaking slower moving vehicles (n=9). No emergency braking response was necessary unless a driving error was made. Subjects were asked to follow speed limits and to comply with local traffic regulation throughout the duration of the scenario. Schematic representations of two typical events are presented in Fig. 1. The left panel illustrates a context where the driver (darker car) is on a 2-way road and approaching a police vehicle parked on the side of the road behind two other vehicles.

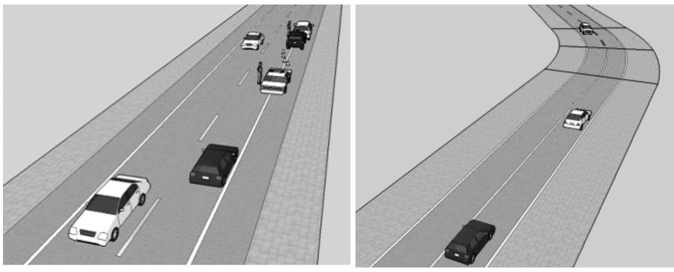

Fig. 1 - Schematic representations of events where avoiding a static object (left panel) and a complete lane change for overtaking a slower moving car (right panel) were necessary

For this event, the speed, when engaging the lane change, varied from 12 to 19 km/h for all but one older driver who nearly stopped before changing lane. For the complete lane change, a wide curve toward the left precedes the lane change (right panel). For all drivers, the speed varied from 45 to 52 km/h before overtaking the slower vehicle after the curve.

Overall, we analyzed 173 events for the young subjects (78 events with a partial lane change and 95 events with a complete lane change) and 153 events for the elderly (69 and 84 events, respectively).

We observed only one accident (elderly driver, during a lane change maneuver). Video streams of the head and the screen were observed simultaneously frame by frame with head movements and car data. Frequency of glance responses to each of the three ROIs (rear-view mirror, left-side mirror, blind spot) was measured. Mean frequency to each ROI were calculated for all drivers.

Data were submitted to a Group (Young, Elderly) x Driving maneuvers (avoiding static object, overtaking slower vehicle) x ROI (rear-view mirror, left-side mirror, blind spot) with repeated measures on the last two factors.

3. Results

All elderly scored 27 or higher on the MMSE and had normal or corrected to normal vision. They also reported having driven more than 5000 km in the preceding year. Table 1 provides a summary of these results.

Tab. 1 – Summary of results (mean values and standard deviations) for the general health evaluation and driving experience

Variable	**Young drivers**	**Elderly drivers**	**P values**	**Variable**	**Young drivers**	**Elderly drivers**	**P values**
Age	21.2 (1.55)	69.25 (3.07)	< 0.001	Snellen visual acuity High contrast	0.82 (0.33)	0.90 (0.13)	> 0.05
Years of experience	4.1 (2.2)	45.1 (10.0)	< 0.001	Snellen visual acuity Low contrast	1.24 (0.56)	1.48 (0.28)	> 0.05
Kilometers per year	6760 (3288)	9683 (4146)	> 0.05	Melbourne edge test	22.77 (1.5)	19.90 (1.3)	< 0.01
Accident within the last years	0.6 (0.8)	0.7 (0.7)	> 0.05	Ankle proprioception acuity, mean of 5 trials	1.08 (0.69)	2.4 (1.02)	< 0.01
MMSE	28.50 (0.07)	27.5 (0.67)	< 0.01	Lower limb touch thresholds	3.87 (0.23)	4.23 (0.33)	> 0.05

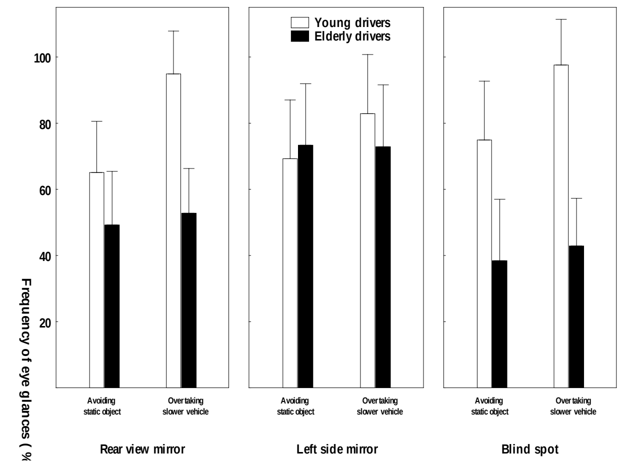

Fig. 2 - Mean frequency of eye glances to the rear-view and the left-side mirrors and the blind spot. Data for the young and elderly drivers when changing lane for avoiding a static object or overtaking a slower vehicle are presented. Errors bars indicate the between-subjects 95% confidence interval

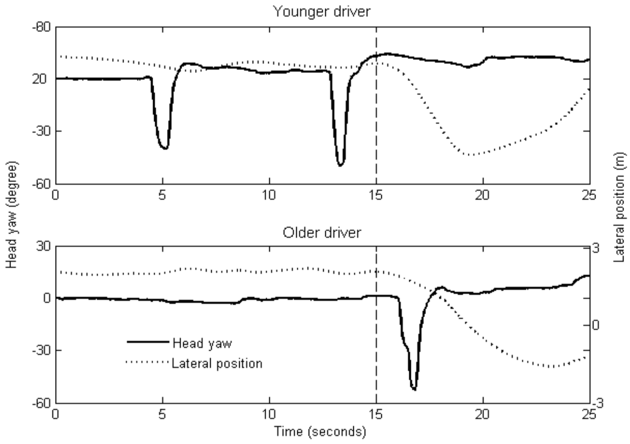

Fig. 3 - Mean Head rotation (degree) and lateral position of the car (meters) in function of time (seconds) for a young (top panel) and an elderly driver (bottom panel)

The main goal of this study was to document whether active elderly drivers, when they change lane, visually sample the environment (rear-view mirror, left-side mirror and blind spot) in a manner similar to young drivers. Fig. 2 presents the frequency of eye glances to the three different ROIs when avoiding a static object or overtaking a slower vehicle for the young and elderly drivers. Clearly, a reduced sampling rate to the rear-view mirror and the blind spot are observed for the older drivers. On average, older drivers glanced at their rear-view mirror on 52% of the events, whereas younger drivers glanced at it on 80% of the events ($p < 0.01$, for the main effect of Group).

Interestingly, the older drivers showed a relatively constant frequency of glances toward this mirror for the two driving conditions (avoiding a static object and overtaking a slower vehicle), whereas younger drivers increased considerably the frequency when overtaking a slower vehicle with a complete lane change (49% vs. 53% for the older drivers and 65% vs. 95% for the younger drivers; $p < 0.01$, for the interaction of Group x Condition). Similar results were observed for the blind spot (38% vs. 43% for the older drivers and 75% vs. 98% for the younger drivers; ps < 0.01, for the main effect of Group and the interaction of Group x Condition).

A similar trend was observed for the left-side mirror ($p = 0.069$ for the interaction of Group x Condition); this effect, however, did not reach the significance level because elderly drivers glanced more frequently to this mirror (on average, 71% compared to 52% for the rear-view mirror, and only 40% to the blind spot). Remarkably, the young drivers showed a very high-frequency of glances at the blind spot when overtaking a slower vehicle before the steering response leading to the lane change (94% of the events).

On the other older drivers seldom glanced at their blind spot before the lane change (on average, only 40% of the events). Often, they glanced at their blind spot during rather than before the onset of the lane change. This situation is illustrated in Fig. 3. All signals are synchronized on the onset of the lane change as documented by the lateral movement of the car. Twenty-five seconds of data are presented and the vertical dashed line indicates the onset of the lane change at 15 s. One can appreciate that, for this event, the younger driver sampled the blind spot (as documented by the large head panning on the top panel) more than once and prior to changing lane. On the contrary, the elderly driver (bottom panel) showed only one head movement toward the blind spot. Moreover, this movement occurred during the lane change.

As mentioned in the methods section, the overall scenario did not include emergency contexts or risky situations. Nevertheless, some of the behaviors observed did lead to risky situations (e.g., a lane change not preceded by specific glances to the blind spot or the left-side mirror although a vehicle was approaching).

4. Discussion

The present study shows that, before lane changes, elderly drivers did not glance at three important ROI (rear-view and left-side mirrors and blind spot) as often as their younger counterparts. This reduced number of glances was particularly apparent for the rear-view mirror and the blind spot. In addition, and contrary to younger drivers, elderly adopted a more stereotypical glance behavior that did not vary with the driving context. On the contrary, younger drivers showed an increased frequency of glances toward the rear-view mirror and the blind spot when overtaking a slower vehicle (presumably a more complex maneuver performed at a higher speed than avoiding a static object). Compared to recent values obtained with on-the-road testing [11] [12], the frequency of glances we are reporting look inflated. Indeed, Olsen and colleagues reported that 46% of the left lane changes had a glance to the rear-view mirror, 53% to the left-side mirror and only 30% to the left blind spot. A major discrepancy with our experiment (beyond the fact that our experiment was conducted with a simulator, whereas that of Olsen et al. was on-the-road) is that we coded glances for a 15-s period preceding the onset of the lane change, whereas Olsen and colleagues limited their analysis to a 3-s period.

For elderly drivers, proportionally more accidents are occurring in complex situations [21]. Presumably, this higher rate of accidents is associated with a higher momentary mental workload created by the driving context. Any attentional deficits [22] and slowness in speed of processing in drivers with cognitive impairment could be expected to exacerbate these effects. We believe these findings are important because they also lead to research work suggesting that elderly drivers are particularly inefficient at monitoring their own performance [23] [24]. Although elderly drivers are apparently aware of what hazardous situations consist of, they seem unable to realize that some of these situations may be dangerous for them. Such an attitude (i.e., high self-rating even in the presence of declining skills) is an obstacle to self-modification of driving habits because an essential aspect of learning consists in evaluating one's errors [25]. Recent work conducted on this issue by Romoser et al. [26] is of utmost importance. Using a driving simulator and eye movement recording devices, they reported having achieved increased drivers' situational awareness through one on one post-training debriefing and feedback. For instance, for reaching an intersection, the provided feedback mostly focused on advising the driver to take more primary and secondary glances toward oncoming traffic primarily through extra head movements. Six months after this one-on-one feedback session, drivers (young and old) were re-tested to check whether or not they had integrated the information learned during the training program. Both young and old drivers reduced their error rate (e.g., failure to glance into adjacent line before merging) by 12.5%. Similarly, Pradhan et al. [27] reported significant improvement in recognizing high-risk situations using a driving simulator for training drivers at increasing active eye movements. To our knowledge, these two experiments are the first attempts at reinforcing behaviors associated with skilled driving (for a discussion of the positive effect of error training in simulator vs. guided learning, see [28]).

5. Conclusion

While on-road assessment of driver training is still considered the reference, driving simulators could offer an efficient and cost-effective means of assessing driver performance. A better knowledge of the elderly drivers' behaviors when changing lane should help in the identification of at-risk drivers and to retrain older drivers to adopt safer and more proactive driving behaviors.

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