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Siby Samuel

Yasuke Yamani
Old Dominion University, yyamani@odu.edu

Danald L. Fisher

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REVIEW

Large reductions are possible in older driver crashes at intersections

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Siby Samuel* PhD
Yusuke Yamani† PhD
Donald L Fisher§ PhD

*Department of Mechanical and Industrial Engineering, University of Massachusetts Amherst, Amherst, Massachusetts, USA
†Department of Psychology, Old Dominion University, Norfolk, Virginia, USA
§Volpe National Transportation Systems Center, Cambridge, Massachusetts, USA
E-mail: fisher@ecs.umass.edu

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Among all crash types, the largest percentage of older driver fatalities occur at intersections. Many explanations have been offered for older drivers' increased risks of crashing at intersections; however, only recently was it determined that older drivers were much less likely to glance for latent threats after entering an intersection than middle-aged drivers. In response, training programmes were designed to increase the frequency of such glances. The programmes have proven effective, doubling the frequency of these glances for up to a period of two years post-training. The programmes take only an hour to administer and are not directly targeted at remediating any of the underlying declines in cognitive, visual or motor function that can explain the decrease in the frequency of glances for threat vehicles among older drivers. The first question we addressed was, what are the basic declines that can explain the decrease in glances for threat vehicles? The second question we addressed was, how did the training programme achieve the results it did without directly addressing these declines? We hypothesise that drivers are learning to decouple hand, foot and head movements in the training programmes and that this serialisation of behaviour essentially sidesteps the major declines in cognitive, visual and motor functions. We provide evidence that the assumptions of the decoupling hypothesis about the capabilities of older drivers when the movements are decoupled, are consistent with the evidence from existing experiments. More research is needed to evaluate this hypothesis.

Key words: drivers, eye movements, intersection crashes, older drivers, training

Several studies have shown that older drivers are much more likely to crash at intersections than middle-aged drivers,[1–3] the relative risk being 10.6 for drivers aged 85 and older compared to middle-aged drivers.[4] Intersections top the list of crash types for drivers aged 70 years and older.[5] The likelihood of traffic violations at intersections is also much higher for older drivers than it is for middle-aged drivers.[6] Older drivers perceive making left turns onto divided highways as more difficult than other turning movements at intersections without signals[7] and in fact, they are more likely to fail to yield the right-of-way, especially when turning left (across traffic as in the USA).[8]

Why might older adults be at such an increased risk of crashing at intersections? Recently, it has been determined that older drivers are much less likely to glance for potential threats when entering an intersection, that is, to look for traffic to the right, to the left or in the opposing lane that might pose a threat.[9] Glances toward latent threats after the driver enters the intersection will be referred to here as 'secondary glances'. Glances toward latent threats as a driver approaches an intersection and while the driver is stopped at the intersection will be referred to as 'primary' glances. Here, we are interested almost exclusively in the frequency of secondary glances, as these are most predictive of crashes.[9–11] The difference between the percentage of secondary glances in older and middle-aged drivers is striking. On the road, for example, middle-aged drivers taking a left turn across traffic (as in the USA) are found to spend 30 per cent of the time while turning making secondary glances toward the region from which a threat vehicle might appear, whereas older drivers spend only 18 per cent of the time doing such.[12] On a driving simulator, Romoser and colleagues[9] found that middle-aged drivers taking a left turn across traffic (as in the USA) spend almost 2.5 times longer glancing for threat vehicles than do older drivers. Finally, again in a driving simulator, Yamani and colleagues[10] found that middle-aged drivers take a secondary glance when entering an intersection fully 56 per cent of the time, whereas older drivers take a secondary glance only 39 per cent of the time.

In light of the above, it is not surprising that training programmes have been designed specifically to increase secondary glances at intersections among older drivers. The two programmes that have successfully done this have used a 3 M training protocol (mistakes, mitigation and mastery), a type of error management training that has been used successfully with novice drivers.[13] In the first training programme, the 54 participants were all active, healthy adults between the ages of 70 and 89 (range: 70 to 88 years; sample mean: 77.54 ± 4.55 years) and were divided into three age groups: 70 to 74, 75 to 79 and 80 to 89 years.[14] The 18 participants within each age group were assigned to one of three treatment groups (active learning, passive learning and control), balanced for gender. Initially, the older drivers navigated in their own vehicle roads with which they were familiar containing multiple intersection manoeuvres (the pre-training field drive). The participants wore a sweatband around their head with a video camera attached, permitting the collection of secondary glance data. We want to emphasise that no one accompanied these drivers on their travels.

After information was recorded on the pre-training field drive, the older driver came to the laboratory and was assigned to an experimental (active or passive training) group or a control group. The active experimental group viewed their pre-training field video and their failures to take secondary glances were pointed out to the older driver by the experimenter (all older drivers failed to take at least one secondary glance), following which, the older driver practised taking secondary glances during intersection manoeuvres on a driving simulator. Feedback on their driving performance in the simulator was given, both visually (the participant wore the same head-mounted camera in the simulator as he or she wore in the field) and verbally. During the simulator training, the participants were explicitly told to take a secondary glance immediately after entering the intersection and glancing toward potential threats. This instruction occurred before the participants initiated their turn except in those few instances where the driver had already turned the wheel while at the stop line. Finally, both the experimental and control groups were asked to take a post-training field drive, both at three months[14] and two years later.[15] In the two post-training assessment, the experimental group made secondary glances 80 per cent of the time, whereas the control group made secondary glances only 40 per cent of the time.

In a second study, some six years later with an entirely different set of drivers, we attempted to determine whether we could do away with the initial field drive and feedback on that drive.[12] A total of 91 older, licensed drivers (42 males, mean age: 75.8 years, range: 67 to 86 years) participated in this study. Two participants were between the ages of 65 and 69 years, 41 between 70 and 74, 31 between 75 and 79 and 17 between 80 and 86 years. Of the 91 participants, 19 were recruited as controls. All aspects of the active training programme were identical in this experiment to the earlier experiment except for the initial field drive. For none of the experimental or control participants in this experiment was such a drive part of the protocol. Rather, the simulator served as the source of the mistakes for error training in the active training group. All experimental groups were evaluated three weeks after training in the field using the same methodology as described in the earlier experiment. In the field, the participants in the active training group made secondary glances at intersections 82 per cent of the time, whereas the control group made secondary glances only 42 per cent of the time. The results of this experiment indicate that a simplified error training protocol, one that is based only on simulator training, has short-term results (three weeks after training) equal to one that requires an initial, time-consuming field drive.

A major question at this point is why the training programmes worked. There are known declines in cognitive, visual and motor functions that could well impact the frequency of secondary glances.[16–22] Yet the training programmes were not designed to address, at least directly, any of these declines. Before offering a potential explanation for how the training programmes might have worked in the absence of targeting behaviour hypothesised to decrease secondary glances, we need to describe what this behaviour is. Thus, the first goal of the current review is to describe the known age-related declines that can explain the greatly reduced frequency of secondary glances at intersections.

Knowing those declines that need to be addressed, the second goal of this review is to determine whether training programmes like the one described either addressed these declines indirectly or perhaps sidestepped these declines altogether. By sidestepped, we mean that the training provided older drivers with a way of navigating turns that bypassed the known declines. The answer may be that the declines do need to be addressed head on but we propose an alternative explanation. Although we do not test the alternative explanation directly, we provide experimental evidence that the assumptions of this alternative explanation are satisfied.

Before moving on, it is important to note that training programmes do exist for older drivers that target age-related declines that could potentially decrease secondary glances at intersections. For example, reductions in the size of the attentional field of view are partly remediable using training programmes which directly address this decline.[23–25] In another study, older drivers' multi-tasking skills were targeted in a gaming environment.[26] The older drivers were asked to switch rapidly between driving and reading signs by the side of the road. After just 12 hours of training, the older drivers' multi-tasking ability was found to equal that of 20-year-olds; however, there was no analysis of the effect of these programmes on secondary glances. Thus, the only training programmes of which we are aware that do increase secondary glances at intersections are those we mentioned earlier.

POTENTIAL EXPLANATIONS FOR REDUCTIONS IN SECONDARY GLANCES

A number of potential explanations for why older drivers may take fewer secondary glances at intersections have been proposed (some of which have been noted above), including age-related declines in the ability to multi-task,[27] in working memory capacity,[28] in distractibility,[29] in the attentional field of view,[30,31] in decision making,[8] in vision[32] and in flexibility.[33,34] Not only can these declines explain the decreases in secondary glances by themselves but these declines in cognitive, sensory and physical abilities may interact and influence safe driving behaviour for older drivers, particularly at intersections.[34,35] Specifically, at an intersection, the driver might have to identify an intersection sign (sensory), regulate the speed of the vehicle (psychomotor), scan appropriately for hazards (cognitive) and potentially execute head movements (physical). The discussion below identifies the cognitive, visual and motor declines that could explain the reduction in crash-critical secondary glances at intersections among older drivers.

Cognitive declines

Here, we present a non-exhaustive review of the various declines in perceptual and cognitive abilities that often accompany aging, as potential factors that could reasonably explain the decrease in the frequency of secondary glances among older adults at intersections.

MULTI-TASKING

First, consider the decline in the ability of older adults to multi-task as a possible explanation of the decrease in the frequency of secondary glances. Declines in multi-tasking can be observed in a number of different paradigms.[27] For example, suppose participants are asked to maintain an image in working memory for some period of time (say tens of seconds). At some point during this period, the participant is interrupted by a secondary task (for example, indicate the sex or age of a face that was presented or ignore the presented face entirely). The interruption is more likely to degrade the memory of the image that was to be recalled for older adults than for younger adults.[27] In another study, in one condition younger and older adults were asked to perform a cancelling task and a tracking task together and the cost of multi-tasking was found to be larger for older than younger adults. Related to the above and in the context of driving, older drivers exhibit greater difficulty performing tasks which require the monitoring of several different visual sources. For example, older drivers following a lead vehicle that was intermittently braking had more difficulty in obeying the traffic signals and signs that were also present in the environment.[36] Such declines in the ability to multi-task could easily decrease the frequency of secondary glances, as during a turn, drivers must not only monitor several visual sources but must also co-ordinate their eye, head, hand and foot movements.

CHANGE BLINDNESS

Second, consider the finding that older drivers' abilities to detect changes in visual scenes decreases with age,[37,38] leading to an increase in what is called 'change blindness'.[39–41] In the change blindness paradigm, participants are presented with two identical images with the exception of a target, which differs between the two, either one after the other twice (the forced choice paradigm – same or different) or multiple times, alternating back and forth (the flicker paradigm). The incomplete encoding of the first image caused by the arrival of a second image while attention is being directed at the first image, typically causes participants to have difficulty in detecting obvious differences in the two images.[42] More central to the current effort, increases in change blindness have a negative impact on drivers' abilities to assess accurately when to turn at intersections. Caird and colleagues[43] used a modified flicker technique where one object within each pair of photographs of an intersection was changed (pedestrian, vehicle, sign or signal). They showed that older drivers were less accurate (at both five seconds and eight seconds flicker intervals) at detecting the change than young drivers.[43] Change blindness could have an effect on the frequency of secondary glances that drivers make at intersections. For example, if older drivers taking a right turn at a stop sign-controlled intersection looked immediately to the left before stopping (a primary glance), saw nothing, looked immediately left again to double check and something new (materialising hazard) was actually present, they (the older drivers) could miss the obvious change in a driving scene, in turn, making them less likely to take a secondary glance to the left as they entered the intersection.

DISTRACTIBILITY

Third, effects of aging on the ability to ignore task-irrelevant stimuli have been examined in a number of different tasks in which attention remains focused throughout. As an example, in the anti-saccade task, participants must direct their attention away from an initial stimulus which appears in the periphery.[44] Older adults made more incorrect pro-saccadic movements, saccades toward the initial stimulus, than younger counterparts,[45] suggesting age-related loss of inhibitory processing. Response times and accuracy in visual search tasks increase for older adults,[46] again suggesting loss of inhibitory processing. Finally, although older adults show age-equivalent performance in an attention-capture paradigm,[29] they appear less successful in using top-down information to avoid task-irrelevant stimuli.[47] If the older adult is more easily distracted by task-irrelevant stimuli, then during a turn, the older adult may be less likely to glance toward a potential threat. Thus, the decline in older adults' abilities to control attention could lead to a decrease in the frequency of secondary glances.

ATTENTIONAL VISUAL FIELD

Fourth, consider age-related shrinkage in the size of the attentional field of view[23] as an explanation for the decrease in the frequency of secondary glances. The attentional field of view is a measure of the size of the area from which people can extract task-relevant information within one fixation when attention is divided.[23,48,49] To measure the attentional field, participants are asked to perform several different tasks. In the divided attention task, they are asked to identify a centrally located target while localising a peripheral target among distractors. Typically, older adults have a more constrained attentional field of view when that size is measured using the selective attention subtest.[32,50–52] The size of the attentional field of view has been negatively correlated with crash risk.[30,53–56] Ball and colleagues[53] for example, assessed 294 older drivers' vision and visual information processing using the useful field of view (UFOV) test. The results suggest that the size of the attentional field of view predicted which older divers had a history of crash problems at higher sensitivity than other functional variables, including ocular health, mental status and contrast sensitivity. Specifically, shrinkage of the attentional field of view revealed a six-fold increase in crash odds (in the previous five-year span).[53] Age-related constriction of size of the visual field of view, as measured by the UFOV task suggests that older drivers will have difficulty detecting threats in the periphery, especially in a real-world environment. Thus, the older driver will be less likely to take a secondary glance, simply because the information that might initiate a secondary glance is not visible to the older driver. Note that this decrease could be due to either the increasing effects of distraction in the periphery or the decreases in central processing speed.[57]

DECISION MAKING

Although older adults may sometimes spend a comparable[58] or shorter[59,60] amount of time performing various decision-making tasks compared with younger adults, older adults' decision speed is almost always slower in driving-related problem-solving tasks.[61] For example, Walker and colleagues[61] asked young and older adults to perform a simulated-route selection task, where message type, levels of route congestion and speed limit on alternate routes were manipulated. The results indicate that older adults took markedly more time to reach their decision than younger adults, while their quality of decision making was similar. Thus, aging can impact older adults' decision speed, especially in a real-world context with a number of motion cues, such as intersection manoeuvres, causing the older drivers to fail to take a secondary glance in the brief time available to them to do so.

Visual declines

The number of different declines in vision among older adults is large.[62] These include losses in visual acuity,[63,64] visual field[32] and contrast sensitivity.[24] All have been proposed as predictors of the increase in crashes,[65–67] although more recently, they have lost the centre stage they might once have had.[30,63,68] Glaucoma is the only decline in vision with aging that has been shown to be a predictor of crash risk.[30] There are reasonable explanations for finding only a weak link between most declines in vision and crashes. On the one hand, crashes typically have multiple causes in addition to vision, such as declines in visual cognitive processing and mental health status.[30] Second, elderly drivers are aware of their visual deficiencies, thereby leading to effective compensatory mechanisms to offset the deficits.[67]

Glaucoma is one reliable predictor which typically develops slowly and without loss of normal sight for years.[69] In fact, the loss initially occurs only in the periphery. Visual acuity is maintained until late in the disease. This loss in peripheral vision but not in central acuity could confuse older drivers, falsely leading them to believe that because they can see well foveally, they can also do so peripherally. This would then explain the loss in the frequency of secondary glances. The older driver with glaucoma would be unlikely to notice threat vehicles in the periphery, something which attracts attention for drivers without glaucoma, when there is motion or other visual cues of an approaching threat in the periphery.

Physical declines

Decreases in the range of motion of the joints, tendons and muscles of the body are common among older adults.[70] Most relevant to the intersection manoeuvres are restrictions in the flexibility of the neck and torso, often seen in older drivers.[33,34,71] Reductions in the flexibility of the neck and torso contribute to an increased likelihood of a crash,[72,73] making it difficult for older drivers to see approaching vehicles within the central stationary field of view.[16] Reductions in the flexibility of the neck and torso could have a direct effect on the frequency of secondary glances. In particular, as flexibility is reduced, presumably older drivers will decrease the frequency of their secondary glances.

EXPLANATION FOR THE EFFECT OF TRAINING ON SECONDARY GLANCES

The above section explored various possible explanations for the finding that the frequency of secondary glances decreases significantly among older drivers. It would appear that all declines in cognitive, visual and motor functions might need to be addressed to achieve large gains in the frequency of secondary glances among older drivers at intersections; however, as we have described, a training programme that takes roughly an hour to administer and that does not directly address these declines, has been shown to double the frequency of secondary glances.[12,14] We suggested that the training programme might sidestep these declines. We now offer an explanation for how this might occur.

What is happening? A hypothesis and an experiment

We have hypothesised that in the training programme, older drivers learned to decouple their head, eye, hand and foot movements during the turn (Y Yamani and colleagues, unpublished data). Typically both older and middle-aged drivers execute coupled head, eye and foot movements to accelerate into an intersection (simultaneously turning the wheel and glancing toward the side), that is, the head, eye and foot movements are executed at the same time. After training, we have hypothesised that the older driver accelerates into the intersection without turning the wheel (foot only movement), then turns his or her head (and eyes) to the areas where potential threats might occur (head and eye movement only) and finally moves the steering wheel in the direction of the turn (hand movement only). We refer to this as the 'decoupling hypothesis'.

Several assumptions of the decoupling hypothesis must be met to provide a viable account of the training effects consistent with older drivers' behaviour. These include that, while travelling straight ahead at intersection locations (equivalent to when the older driver first enters an intersection), older drivers can:

1. turn their heads to the side as frequently as middle-aged drivers even without training;
2. maintain the position of their vehicle in the lane while doing so; and
3. gather information from the glances to the side.

An experiment conducted to evaluate the assumptions of the decoupling hypothesis showed that, when older and middle-aged drivers were asked to scan for information that appeared on the side of a straight segment of road (Y Yamani and colleagues, unpublished data):

1. untrained older drivers turned their heads to the side as often as middle-aged drivers in the straight sections;
2. older drivers were equally able to maintain a stable headway while searching for information on the side of the road; and
3. older drivers detected information to the sides as often as did middle-aged drivers.

Given the assumptions of the decoupling hypothesis are satisfied, this implies that if older drivers could successfully decouple their motor movements, then in theory, they were capable of increasing the frequency of their secondary glances to what it had been when they were middle-aged.

Which declines are diminished if older drivers can decouple their movements?

As the training did not specifically target any of the cognitive, visual or motor declines that potentially explain the decrease in the frequency of the secondary glances of older drivers at intersections, the question now becomes how these declines were sidestepped. Our answer is the decoupling hypothesis that assumes that older drivers could decouple their head, hand and foot movements. Consider how the decoupling hypothesis can explain how the categories of cognitive decline might have been sidestepped. First, it is known that multi-tasking abilities decrease in older adults. Nothing in the training programme served to improve the multi-tasking abilities of the older drivers but the need to multi-task was reduced by decoupling the various different movements. After training, it is hypothesised that the various elements of a turning manoeuvre were performed sequentially and thus, multi-tasking was no longer a potential issue. Second, consider the declines in working memory capacity and in particular, the increases in change blindness with age. The training programme did nothing to lessen this decline. Third, consider the increases in distractibility. Again, there is nothing that the training programme did to diminish increases in distractibility. Fourth, consider the decrease in the size of the attentional field of view. Again, without intending to, we may have sidestepped the decrease in the size of the attentional field. When older drivers do turn their heads to the side, as they did after training, they reduce greatly their need to rely on detecting threats in the periphery; all the while, they are processing information directly ahead of the vehicle. Finally, consider the increase in the time it takes drivers to make a decision. Again, we may have unknowingly sidestepped the potential problems created by this increase in decision-making time, by serialising the different movements in the turn. We appear to have potentially sidestepped three of the five possible cognitive declines. The remaining two declines (change blindness and distractibility), if addressed, might improve the training even more.

Consider next the declines in vision and flexibility. With respect to vision and in particular to glaucoma, if older drivers after training are taking more secondary looks because they can decouple the various elements of turning, then the effects of glaucoma on the frequency of secondary looks should be reduced because drivers no longer need to rely as much on their peripheral vision to warn them of an impending threat. They are already glancing to the side. With respect to flexibility, consider a turn to the right at a stop sign-controlled T-intersection. The driver needs to take secondary glances both toward the left and the right. If the driver enters the intersection and immediately begins turning to the right, something suggested in recent research,[74] then at the start of the turn, the driver may well be looking 45 degrees to the right. That means a glance to the left could require a head rotation of 90 degrees or more; however, after training, the older driver is hypothesised to proceed straight into the intersection before glancing. Thus, the extent of head rotation for the trained driver could be less than half that for the untrained driver. We may have sidestepped both the vision and flexibility declines.

DISCUSSION

There exist several potential explanations for why older drivers are more likely to crash at intersections that rely on declines in core cognitive, visual and motor functions. While they have been tied to a number of different types of behaviour at intersections which could increase the crash risk among older drivers, they have not been linked directly to decreases in the frequency of secondary glances. Decreases in the frequency of secondary glances were identified only recently and have been clearly linked to crashes, at least on a driving simulator.[10] The question was which, if any, of the putative declines in cognitive, visual and motor functions could explain the decrease in the frequency of secondary glances among older drivers. Theoretically, this is of interest in and of itself but practically, if one is going to increase the frequency of secondary glances, it is important to know which of these three declines that occur with aging can plausibly explain the decrease in secondary glances among older drivers. If this is the case, then a question arises as to how a training programme which directly targeted none of these declines could increase the frequency of secondary glances by a factor of two, from 40 to 80 per cent. Our answer here is that the training programme which was developed using what has long had a proven effect on novice drivers' performances, unwittingly gave older drivers a strategy for negotiating intersections that essentially let them successfully sidestep several declines. There is still much to be done, both theoretically, where experiments need to be run which provide the evidence one needs to be certain that the declines in cognitive, visual and motor function are indeed being sidestepped by the training programme as hypothesised by a decoupling of the hand, foot, head and eye movements, and practically, where a randomised clinical trial of the training programme needs to be conducted with crashes as the outcome variable. Other limitations exist as well. We do not know whether the drivers who were trained are increasing their glances only when being measured and not in the hurly burly of everyday driving. Ours is the only laboratory that has shown these results. Perhaps we are doing something of which we are unaware that could not easily be replicated. Nevertheless, the results are encouraging and suggest that training programmes that take only an hour to complete, double the frequency of secondary looks on the road for up to two years.

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