ABSTRACT

Literature on older driver involvement in crashes shows that their involvement in intersection crashes increases with age, and that they have problems in dealing with complex environments such as uncontrolled intersections. They also exhibit the effects of age-related visual and cognitive deficits. The aim of this study was to confirm the existence of similar crash involvement patterns among older drivers in Queensland, and to identify potential contributing factors to crash risk for further research. Five years of crash data were collected and odds ratios were plotted by age category for combinations of the following variables: intersection vs midblock, rural and urban areas, day and night, and unsignalised and signalised urban intersections. The patterns largely confirmed existing research, and issues concerning relative visual and cognitive load in urban and rural areas at night and by day were identified.

INTRODUCTION

The proportion of older people in the population is increasing (1). Due to cohort effects, the proportion of older people who are licence holders is also increasing (1). There is evidence that older drivers have a greater risk of involvement in crashes and a greater vulnerability in crashes (1,2,3). A number of factors are believed to interact in contributing to this increased risk of involvement, including age-related visual changes, age-related reduction in cognitive abilities such as decision-making, and reduced physical ability to perform. Intersection crashes present particular problems for older drivers (2,3,4).

The Queensland University of Technology has been conducting research into the contribution of age and visual impairment to driving performance, both on the Mt Cotton driver training track and on normal roads. Queensland Transport and the Queensland University of Technology have commenced joint research which extends the current research program, with a view to examining the how the interaction between the older driver and his or her environment contributes to increased crash risk, and how changes to the driving environment might reduce this crash risk. The research will add to the information generated by a project undertaken by the Accident Research Centre at Monash University for Austroads on road environment and design for older drivers (5).

In preparation for the joint research it was decided to examine Queensland crash data to confirm the patterns of crash involvement and responsibility found in the literature, and to identify suggestive findings which might be worthy of follow up.

FINDINGS FROM THE LITERATURE

The main factors which emerged from a brief review of literature on the older driver/driving environment interaction at intersections were:

- Involvement in intersection crashes increases with age (2,3,4)
• Responsibility for crashes increases with age (6).
• Older drivers have more difficulty than younger drivers in coping with complex situations, of which intersections are an example (2,4,5)
• Uncontrolled intersections present more problems for older drivers than controlled intersections (3)
• The increase in crash involvement with age is contributed to by both visual and cognitive deficits, which interact (7)
• Two particular problems which older drivers have at intersections are gap selection and decision-making (5,8) particularly in rural areas (8)

A noteworthy feature is the distinction between visual and cognitive deficits, and their interaction, as contributing factors to older driver crash involvement at intersections (2,5,7). Negotiation of intersections requires more information processing and judgement than driving along a midblock, hence will impose a greater cognitive load. Some intersections are more complex than others, once again contributing to cognitive load. Urban intersections exhibit a greater range of complexity than rural intersections, being more likely to have greater numbers of signs and signals, heavier traffic and multiple lanes. On the other hand, rural intersections on high-speed roads require more precise (or conservative) judgement of gaps and speeds of approaching vehicles. The difference in crash involvement at controlled and uncontrolled intersections might also be expected to translate to a difference between signalised and unsignalised intersections, because negotiation of intersections controlled by signs once again requires gap selection and judgement of oncoming vehicle speeds.

The impact of impairment of visual ability is difficult to distinguish from impairment of cognitive ability. Some of the factors which impose a cognitive load at intersections may also impose a visual load, such as a high number of signs, heavy traffic, etc. As for cognitive load, visual load would be higher in urban than in rural areas, and at intersections rather than midblocks. However, visual problems would also be expected to show up more at night than during the day, and the effects of changes to glare sensitivity and contrast sensitivity would be more marked in rural than urban areas. Interestingly, night conditions could make negotiation of signalised intersections easier than during the day, given that the traffic signal would be easier to see.

It should also be borne in mind that while visual and cognitive ability decline with age (9,10) there is evidence that older drivers compensate for these changes by controlling their exposure or changing their driving behaviour (3,4).

METHOD

Limitations to the Queensland Transport Road Crash Database, and small numbers of crashes in some cases, precluded a full attempt at confirmation and exploration of the findings and implications outlined above. Instead, the following hypotheses were generated for investigation:

• relative to their involvement in midblock crashes, drivers should show increasing involvement in intersection crashes with increasing age, both overall and for urban and rural areas
• for intersection crashes in both urban and rural areas, drivers should show increasing degrees of responsibility for the crash with increasing age
• for intersection crashes in urban areas, drivers should show increasing involvement in unsignalised (relative to signalised) intersection crashes with age
• for both signalised and unsignalised urban intersections, drivers should show increasing degrees of responsibility for the crash with increasing age
• the increase in risk with increasing age should be enhanced under night time conditions and in rural areas.

Crash data for the five year period 1995-99 were collected for all drivers killed, hospitalised or receiving medical treatment as a result of a motor vehicle crash. The data were disaggregated by age group of driver (0-24, 25-39, 40-59, 60-69, 70-79, 80+), location (urban/rural), time of day (day/night) and road environment (intersection/midblock), and within urban intersections by signalised/unsignalised. Police opinion as to the degree of fault of each driver was also collected for all categories.
χ² tests were carried out to test for independence of age category for intersection vs midblock comparisons, “more at fault” vs “less at fault” comparisons, and unsignalised vs signalised comparisons. The criterion α value was .05. Odds ratios were calculated for each age group for the comparisons of interest:

- intersections/midblocks for urban (day, night, all) and rural (day, night, all)
- more/less at fault for urban (day, night, all), rural (day, night, all), urban unsignalised (day, night, all) and urban signalised (day, night, all)
- unsignalised/signalised urban intersection for day, night.

The odds ratios were plotted to check for age related trends.

RESULTS

The data and figures were divided into four groups for analysis:

1. Crash involvement at intersections vs midblocks, urban/rural, day/night
2. Responsibility for intersection crashes, urban/rural, day/night
3. Crash involvement at urban unsignalised vs signalised intersections, day/night
4. Responsibility for urban intersection crashes, unsignalised/signalised, day/night

Crash involvement at intersections vs midblocks, urban/rural, day/night

Tests of independence all showed a significant association between age category and crash involvement at intersections vs midblocks, in most cases with \( p < .001 \), for the following populations:

- Urban crashes
- Rural crashes
- Urban day time crashes
- Urban night time crashes
- Rural day time crashes
- Rural night time crashes

Plotting of the odds ratios (Figures 1, 2 and 3) shows that (apart from one aberrant ratio) the significant value of the test statistics reflects increasing crash involvement in intersection crashes relative to midblock crashes as age increases.

The odds ratios were plotted on graphs with two X-axes to enable comparison of the shape of the relationship between age and intersection crash involvement. In some cases the zero point was adjusted to assist comparisons.

Figure 1 shows that crash involvement rises more slowly with age in rural areas until the 80+ age category is reached. Comparing the X-axes in Figure 3 shows that the intersection crash involvement of older drivers in rural areas doubled at night.
Figure 1: Odds of driver crash involvement at intersections vs midblocks by age, urban vs rural.
Responsibility for intersection crashes, urban/rural, day/night

All but one test of independence all showed a significant association between age category and the responsibility categories “more at fault” vs “less at fault” in intersection crashes, in most cases with $p < .001$, for the following populations:

- Urban intersection crashes
- Rural intersection crashes
- Urban day time intersection crashes
- Urban night time intersection crashes
- Rural day time intersection crashes

The non-significant result was for:

- Rural night time intersection crashes (Figure 6, dotted line – note that the final point has been calculated from pooled 70-79 and 80+ data, and hence would be further right if the software allowed it).
Plotting of odds ratios (Figures 4, 5 and 6) shows a J-shaped curve, with 0-24 year old drivers being more at fault than drivers aged 25-59 in urban intersection crashes (Figure 5), and drivers aged 25-69 in rural intersection crashes (Figure 6). After these ages responsibility rises with driver age to much higher levels than for 0-24 year olds.

Comparing the X-axes in Figure 4 shows that responsibility for intersection crash involvement rises more quickly with age in urban areas than in rural areas. Comparing the X-axes in Figures 5 and 6 shows that responsibility for intersection crash involvement rises more quickly with age at night in both urban and rural areas. Note that the final odds ratio (age 80+) for night time in Figure 5 had a denominator of zero, which was arbitrarily increased to 1 for plotting.
Crash involvement at urban unsignalised vs signalised intersections, day/night

Tests of independence both showed a significant association between age category and crash involvement at unsignalised vs signalised intersections, with $p < .001$, for the following populations:

- Urban day time intersection crashes
- Urban night time intersection crashes

Plotting of the odds ratios for crash involvement at unsignalised vs signalised intersections by day and at night (Figure 7) shows that the significant association between age and urban intersection type at night is not in the form of either the increasing involvement curve seen in Figures 1-3, or in the J-shaped form seen in Figures 4-6, and is difficult to interpret. By day the involvement ratio is more J-shaped, with relative involvement at unsignalised intersections decreasing after age 0-24, and increasing above the 0-24 level after age 69.
Responsibility for urban intersection crashes, unsignalised/signalised, day/night

Tests of independence all showed a significant association between age category and the responsibility categories “more at fault” vs “less at fault” in urban intersection crashes, with \( p < .001 \), for the following populations:

- Unsignalised urban intersection crashes
- Signalised urban intersection crashes
- Unsignalised day time urban intersection crashes
- Unsignalised night time urban intersection crashes
- Signalised day time urban intersection crashes
- Signalised night time urban intersection crashes

Plotting of the odds ratios (Figures 8, 9 and 10) generally shows a J-shaped curve with responsibility increasing with age beyond middle age as in Figures 4-6, although responsibility for crashes at signalised intersections by day (Figure 9) and overall (Figure 10) do not exhibit increased 0-24 year old responsibility.

Comparing the X-axes in Figures 8 and 9 shows that responsibility for intersection crash involvement rises more quickly with age by day at both unsignalised (Figure 8, though not very strongly) and signalised intersections (Figure 9), although in both cases the responsibility of 0-24 year olds increased more strongly at night than by day. However, note that the final odds ratio (age 80+) for night time in Figure 9 had a denominator of zero, which was arbitrarily increased to 1 for plotting.

Figure 10 shows that responsibility for intersection crash involvement rises more slowly with age (and when moving down to the 0-24 category) at signalised intersections than at unsignalised intersections until the 80+ age category is reached.
DISCUSSION

Some of the results confirmed that previous findings in the literature apply to Queensland. Older drivers were more likely to be involved in intersection crashes, and were more likely to be responsible for the crash. This was true in both urban and rural areas, at night and by day, and (with respect to responsibility) for unsignalised and signalised urban intersections. Indirect confirmation of higher involvement at uncontrolled intersections was found in the higher crash involvement for older drivers at urban unsignalised intersections by day, although the increase was modest and was not evident at night.

Other results were suggestive of the contribution of other factors to crash risk. The doubling of crash involvement at rural intersections at night suggests increased visual load, as does the multiplication of increased crash responsibility with age at night for both urban and rural intersections. “Multiplication” refers to situations where the odds ratio curves for two categories are much the same at younger or (for J-shaped curves) middle age, but then rise more rapidly for one category than for the other as age increases.
Crash responsibility also multiplied with age at urban signalised intersections, but by day rather than at night. However, this may also suggest increased visual load. There may be many competing sources of visual information at an urban intersection by day, interfering with driver attention to the traffic signals, while at night the illumination of the traffic signals makes them more salient.

Cognitive load effects are suggested by other findings. Crash involvement at urban intersections increases steadily with age, whereas crash involvement at rural intersections increases more slowly, before rising sharply for drivers 80+ years old. As urban intersections tend to be more complex on average, as well as having a wide range of levels of complexity, the steady rise in crash involvement might reflect a steady deterioration in cognitive ability with age. The jump in rural areas after 80 years may be due to a threshold level of cognitive impairment being reached. The same comment can be made about trends in crash responsibility at urban signalised and unsignalised intersections by age, which suggest that cognitive load rises more steadily with age at unsignalised intersections, which present greater demands on decision-making, while responsibility at signalised intersections rises more slowly but then jumps after 80 years of age.

This apparent threshold effect may itself be the result of a further interaction between cognitive impairment and compensatory behaviour. It is generally noted that older drivers compensate for their declining abilities in various ways, but that at some point loss of judgement means that the compensatory efforts are no longer effective, and may even be counterproductive, as observed for crossing decisions among older pedestrians (11).

Some of the results above are more equivocal than those already mentioned. The multiplication of increased crash responsibility with age at intersections in urban compared with rural areas could be due to either increased cognitive load, or increased visual load, or both. It is also noteworthy that urban unsignalised intersections seem to present the same difficulties day or night.

It must be emphasised that the analysis of crash data used here is a relatively crude means of establishing evidence for visual and cognitive load effects. The labels of “visual load” and “cognitive load” are also crude, as they cover a number of factors which operate in different and sometimes contradictory ways. For example it was noted above that there may be less visual load at signalised intersections at night because the traffic lights are easier to see, yet elsewhere the presumption was made that night conditions would lead to greater visual load because of glare sensitivity and contrast sensitivity. A more refined and thorough approach is needed.

Should further study be devoted to the issues raised here, two questions are worthy of some attention. First, what is the explanatory role of visual and cognitive load in the multiplication of crash involvement or responsibility under the circumstances identified here? Second, is there a threshold effect of cognitive load, such that crash involvement and responsibility are unable to be addressed beyond 80 years old?

The most important conclusion to be drawn from these analyses is that driver age is not a discrete factor modifying crash involvement and responsibility. It is sensitive to the environment in which road use occurs: intersections or midblocks, urban or rural roads, by day or at night, at signalised or unsignalised intersections. If the characteristics of these environments which contribute to crash risk can be identified, it should be possible to improve the traffic environment to reduce the crash risk of older drivers.

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REFERENCES


