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How much visual road information is needed to drive safely and comfortably?

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Abstract

The questions “how much visual information from the road is required for proper driving?”, and “how do people cope with a visually ambiguous road configuration?”, were explored in an advanced driving simulator.

Sixteen young and sixteen elderly drivers completed two test rides on a rural road that was divided into five sections of 2 km, at each section a road element (e.g., delineation, roadside marker) was added or removed. During the rides, performance (lateral position, speed) and heart rate were recorded continuously, and before transition to a new section drivers gave a rating on invested effort and on visibility of the (previous) road course. The experiment’s goal was to determine whether a shift in driving behaviour could be noticed at a certain amount of visual information.

The main threshold found, for both age groups, lies between roads with ‘no delineation on the road surface at all’ and ‘a centre-line’. Elderly drivers, however, appeared to need the visual aid of the centre-line to a greater extent than young drivers, and in general they drove slower and regulated their information input in this way.

A visually ambiguous road situation concluded the experiment. The participants drove on a centre-lined road towards a junction where the road forked to the left and right. The left-hand road was a road without delineation but with lampposts, the right-hand road was a continuation of the centre-lined road without lampposts. In particular elderly drivers were confused by this situation and chose the road with lampposts more often. This finding supports the assumption that with increasing age people are more easily confused by ambiguous cues .

Introduction

In order to keep a vehicle on the road clear perception of that road is obviously crucial. The appearance of a road can be very different, not only is there a wide variety in road layout and delineation internationally and nationally, temporary factors as daylight also affect road perception.
With respect to delineation McKnight, McKnight and Tippetts (1998) found that lane lines with low contrast coincide with reduced lane-keeping performance. However, only when delineation is hardly visible (i.e., low contrast) these effects were found. Riemersma (1979) also found improved lane-keeping control on roads with a clear road marking compared with roads with less clear marking. Similarly, a low contrast between road edge and road shoulder is more difficult to perceive and can lead to steering inaccuracy. In an effort to keep the vehicle on the road drivers can even overreact in steering and end up on the other side of the road. Edge-lines can counteract this effect (Steyvers & De Waard, 2000), and improve lane visibility, especially in darkness.
In general a reduced lane width leads to reduced driving speed (Yagar & Van Aerde, 1983) while sign posts (Kallberg, 1983) and road markings (Tenkink, 1988, Steyvers & De Waard, 2000) provide guidance and lead to increased driving speed. Landwehr (1991) recommends optical posts in addition to road-side pavement markers. Reason for this advice are results from research on visual perception during driving (Land & Horwood, 1996) that show that drivers search for visual elements to estimate road course in curves and beyond. Placement of these vertical elements may improve curve tracking, but the height of these objects should be clearly above eye-level, such as lampposts (see also Riemersma, 1979).

When looking at accident data, in the US in Arizona, Taylor, McGee, Sequin and Hostetter (1972) found that adding edge lines to a formerly non-delineated road reduced accidents with 80 %. In England, however, Willis, Scott and Barnes (1984) found inconclusive accident data comparing situations before and after adding road marking. Driving speed did not change. The authors conclude that on the basis of their study no recommendation with respect to adding delineation or not to roads can be given. The OECD (1990) evaluated several studies on effects of road characteristics and comes with a similar conclusion, in some studies positive safety effects of road accidents were found, in others more accidents are reported. With respect to type of road marking in general the conclusion is that non-continuous lines improve speed estimation or impression (e.g., Landwehr, 1991).

In contrast, visual elements such as delineation have also been removed in an effort to reduce speeding by providing less guidance. In an experiment in the Netherlands edge-lines were completely removed to reduce their guiding property. On-road evaluation data (De Waard, Jessurun, Steyvers, Raggatt & Brookhuis, 1995) and accident data (Steyvers, 1999) have shown that this measure works as intended. Other perceptual countermeasures such as hatched centre areas have also been found to reduce driving speed by affecting speed perception (Godley, Fildes, Triggs & Brown, 1999).

In general the focus of the scientific community is on information overload in driving. Overload can result from the use of additional devices such as mobile phones (e.g., Brookhuis, de Vries & De Waard, 1991, Goodman, Tijerina, Bents & Wierwille, 1999), or other distracting new in-car telematics (Fairclough, Ashby & Parkes, 1993, Summala, Nieminen & Punto, 1996, Lamble, Kauranen, Laakso & Summala, 1999). Increased road complexity is also a factor that has been studied (De Waard, 1991, Richter, Wagner, Heger & Weise, 1998, Verwey, 2000, Kantowitz & Simsek, 2001), but less is known about the minimal visual properties a road has to have to give enough guidance to drive safely. The road authority's interest in this question is obviously also a matter of efficiency; less delineation means less installation costs as well as less maintenance costs. However, care has to be taken that the needs of all drivers are taken into account. In an ageing society the proportion elderly drivers increases, and with increasing age amongst others visual acuity reduces. Decisions to remove visual cues should take this group of drivers into account.

With respect to visibility and guidance of a road layout and appearance, the following research questions can be asked:

- How is lane keeping affected by road appearance?
- Do drivers adapt their speed in conditions where there is less information and guidance?
- Is there a shift in behaviour after adding certain delineation or other visual information?
- How do drivers respond to conflicting visual information?

In the present study the focus is on the road itself. In the real world there is often other traffic that affects behaviour, but that is not studied here, only the road's appearance is changed.

Method

Thirty-two volunteers were recruited via local media and were paid for participation. Sixteen of them were young (25-40), sixteen elderly (55-70 years). To get used to driving the simulator participants first completed a practice session until a stable driving level was attained. In general this took about ten minutes. Personal information on driving experience was gathered, and ECG electrodes were attached to participants' chest.

The driving simulator of the Department of Psychology of the University of Groningen was used for the experiment. The simulator was fixed based, and consisted of a car (a BMW 525) with original controls linked to a Silicon Graphics computer that recorded driver behaviour and computed the road environment. The road environment was projected on a screen that covered 165 degrees angle horizontal view, and 45 degrees vertical view (for details on the simulator see Van Wolffelaar & Van Winsum, 1995).

In the simulator test rides were completed on a road in a rural environment. The road was divided into five 2 km sections, after each section visual information in the form of a road element was added or removed. A road element was defined as delineation, roadside markers or lampposts. The appearance of the road was as follows:

1: "no delineation": dark asphalt road surface only, no delineation, no markers nor lampposts
2. "centre-line": discontinuous 0.10 m wide and 3 metre long centre-line only
3. "centre-line + roadside marker" discontinuous centre-line plus white roadside marker
4. "full delineation" same centre-line and roadside markers plus continuous edge-lines
5. "lampposts" as condition 4, plus lampposts

In figure 1 two snapshots of the road are shown.

>>> Figure 1 about here

All participants completed the rural road ride twice in different order, 50 % started the first ride with "no delineation" ending with "lampposts", the other 50% in opposite order. The second ride was in reversed order compared with the first ride. In between the rides there was a short break. During all rides there was no other traffic present.

The third ride on a rural road was on a centre-lined road that after 2 km forked into a road without delineation but with lampposts, and into a centre-line delineated road. The ambiguous non-delineated road is referred to as "ghost-road". The expectancy problems that can be expected in a forking road design have been described by Alexander & Lunenfeld (1986). A snapshot of the junction used here is shown in figure 2.

>>> Figure 2 about here

After the rides a three minutes rest period concluded the experiment. Heart rate was measured during this period while the participant sat relaxed in the parked vehicle.

During the rides the following measures were taken or were later derived:

Driving Performance measures
Driving speed on each section was registered at 10 Hz sample rate, later average and standard deviation were calculated. The same applies to lateral position on the road, average and *sd* (SDLP, Standard Deviation Lateral Position) were calculated for each section. To counteract learning effects data of the two sessions (one with increasing visual elements, one with decreasing elements) were averaged per participant.
In the condition of the ambiguous road, route choice (ghostroad vs. centre-line delineated road) was registered.

Physiological measures
Heart rate's R-peak was detected with an accuracy of 1 millisecond, and the inter-beat-intervals were calculated and stored on disk On these data power spectrum analyses were performed. Frequency analysis has as a major advantage that heart rate variability is decomposed into components that are associated with biological control mechanisms (Kramer, 1991). Of the frequency bands that have been identified (see L.J.M.Mulder, 1992), the so-called 0.10 Hz component is related to short-term blood pressure regulation and has been found to be suppressed in conditions of mental effort and increased task demands (Mulder & Mulder, 1981, Aasman et al., 1987, Vicente et al., 1987, Backs & Seljos, 1994, De Waard & Brookhuis, 1997). To reduce inter-individual differences heart rate is compared with the rest measurement and a Ln-transformation was performed on the power spectra data (Van Roon, 1998).

Self-reports
On the last 300 metres of a section no performance measures were taken, but two ratings were required. A rating of effort and a rating of clearness of road course had to be given by the participants. They were prompted to do so by projection of the questions on the screen, first "How effortful (0..10) was it for you to drive the previous section? (0 = no effort)" and then "how clear (0..10) was the road course ? (0 = not clear at all)". Before the test rides this 'clearness'-rating had been explained as to be a judgement on the visibility of the road's course. The score was spoken out aloud (there was a microphone in the car) and written down by the experimenter.

Instruction
Speed instruction was varied between participants. Half of them were told that they would be driving on a 60 km/h speed limit road, the other half were told the speed limit was 100 km/h. Although driving a curve at 100 km/h was possible, it was quite fast for the radius of 200 m. Purpose was to influence response set, or cognitive representation, in terms of road type and events that could be expected. These are different for a 60 and 100 km/h speed-limit road. No events like e.g. farming vehicles were added to the conditions (in fact, there was no other traffic at all), so in the end all that was influenced were expectations. The instruction was given at the beginning, and not repeated during the experiment.

Hypotheses
- Between one of the successive sections there is a more or less abrupt change in behaviour in terms of vehicle parameters, physiology, or subjective ratings. This shift in behaviour indicates a break in critical visual road information.
- Speed instruction (response set) has an influence on this threshold, at a slower speed(instruction) less visual information is needed to drive safely and comfortably compared with driving at a higher speed
- Elderly drivers require more or different visual information to maintain task performance.
- Drivers will be confused by the ambiguous road forking and 50 % will choose the ghost road. As elderly drivers benefit most from redundant information (e.g., De Waard, Van der Hulst & Brookhuis, 1999) the conflicting information will confuse them more than young drivers.

Statistical tests were performed using SPSS 10.0 for Windows.

Results

Participants
As intended, a total of 32 participants completed the test rides of which sixteen were young (11 male), and sixteen elderly (10 male). Average age of the young participants was 31.1 years (*sd* 4.9), of the elderly 67.4 years (*sd* 6.0). The young had driven an average total distance of 150,000 km (*sd* 170,000) and had held a licence for 10 years (*sd* 6.3), the elderly had an average total driven distance of 800,000 (*sd* 1,100,000), and had held their licence for 37.5 years (*sd* 7.5). Annual mileage did not differ between the groups, 19,000 km/year (*sd* 19,500) for the young, and 12,500 km/year (*sd* 7,000) for the elderly (Mann-Whitney, $Z = -0.65$, NS).

The focus of tests is on the following effects: main effect of age group, main effect of instruction (60/100 km/h), effect of road appearance (section).

Speed

In figure 3 the average speed per group, instruction and section is displayed. Instruction had a significant effect on speed choice ($F(1,28) = 21.1$, $p < 0.001$). Very clearly visible is the effect of age group ($F(1,28) = 7.62$, $p = 0.010$) and the interaction between instruction and age group ($F(1,28) = 5.01$, $p = 0.033$). Young drivers drove faster, especially after the instruction that the road was a 100 km/h speed limit road. Linear trend analyses over road appearance was marginally significant ($F(1,28) = 3.99$, $p = 0.056$). Pairwise comparisons (corrected for multiple comparisons: least significant difference) showed that the "lamppost" condition differed significantly from all other conditions, but note that drivers drove *slower* on this section (see figure 3).
Variability in speed as indicated by *sd* speed (figure 4) show a higher variability in speed for elderly drivers compared with the young ($F(1,28) = 20.4$, $p < 0.001$), but no effect of instruction ($F(1,28)=3.34$, NS). No effect of road appearance on *sd* speed was found, with the exception of the road with lampposts compared with the fully delineated road. Variability in speed was higher on the road with lampposts.

>> FIGs 3 and 4 about here

Lateral position
Lateral position was measured as distance from the centre of the driver's seat to the road edge. Only main effects of instruction and road appearance were found. The higher the speed instruction, the more towards the road's centre drivers drove ($F(1,28) = 5.25$, $p = 0.030$).
From figure 5 it is very clear that on the non-delineated road drivers chose a far more central position. The moment that in addition to a centre line elements to the right of the driver are added (roadside marker and edgelines) average lateral position is further away from the road edge compared with the centre-lined road. Pairwise comparisons show a significant difference between all road appearance conditions with the exception of the comparison between the centre + roadside marker vs. completely delineated road.
SD lateral position (SDLP), a measure of vehicle swerving on the road, is not different between groups nor is it different as a result of instruction (figure 6). Road appearance, however, does have an effect on SDLP. Especially on the non-delineated road SDLP is very high. All road appearance conditions differ from each other when compared pairwise, again with the exception of the comparison between the centre + roadside marker vs. completely delineated road. Trend analyses on road appearance reveal a square trend ($F(1,28)=31.2$, $p < 0.001$).

>> FIG 5 and 6

Self-reports
After each section participants were asked how effortful driving over that section had been, and how clear they rated the road's course. In figure 7 it can be seen that driving over the non delineated road required most effort. Each added road element reduced effort, with the exception of the section where lampposts were added. Differences in rating between age groups were not significant. Both speed instruction ($F(1,25) = 4.03$, $p = 0.056$) and the interaction between group and instruction ($F(1,25)= 3.04$, $p = 0.094$) were marginally significant. This means that there is a tendency that driving in the higher speed instruction requires more effort, especially for the elderly driver. Pairwise comparisons were significant between all road appearance conditions with the exception of the lamppost vs. full delineation conditions.
Ratings of clearness of road course (figure 8) increased linearly with added elements ($F(1,25) = 92.9$, $p < 0.001$). All road appearance conditions differed significantly from each other. There were no significant main effects of instruction or group, but the group by instruction interaction approached significance ($F(1,25)= 3.69$, $p = 0.066$). For the elderly driver the road's course was more clear if they were told it was a 60 km/h speed limit road, and were driving slower than the 100 km/h speed limit group.

>>> FIG 7 and 8

Physiology
There was no effect of speed instruction on heart rate ($F(1,26) < 1$, NS), therefore data displayed in figure 9 were averaged over these conditions. In figure 9 the average Inter-beat-interval (IBI) in heart rate is shown. IBI relates to heart rate as 60.000/IBI (in ms) = heart rate (in beats/minute, bpm). Average heart rate was 76 bpm during the rides, and 68 bpm during rest ($F(1,26) = 54.0$, $p < 0.001$). Only very small differences in heart rate were found, but linear trend analysis showed a significant

decrease in heart rate over road sections ($F(1,26) = 4.63$, $p = 0.041$). Pairwise comparisons revealed that only during driving over the non-delineated road heart rate was significantly elevated compared with the other road appearance conditions.
Heart rate variability in the 0.10 Hz component band did not show a trend ($F(1,26) < 1$, NS) nor was found to be different between road sections. The Ln-transform on all sections was for the young drivers on average 7.1 (during rest 7.7), for elderly drivers while driving on the road 5.5 (during rest 6.0). The difference between driving and resting was in the expected direction (more suppressed during driving reflecting more mental effort), but the difference was not significant ($F(1,26) = 2.58$, NS). Only the difference between groups ($F(1,26) = 26.4$, $p < 0.001$) was statistically significantly different.

>>> FIG 9 here

Ghost road
The majority (81%) of the younger drivers continued to follow the centre-line road from the point the road forked into a non delineated road with lampposts and a centre-line delineated road (see snapshot figure 2). Fifty percent of the elderly took the non-delineated road, and 50% followed the centre-line delineated road.
In figure 10 and 11 respectively the average inter-beat interval and the 0.10 Hz component (Ln-transformed) as calculated over periods of 30 seconds are displayed. As on the x-axis time in steps of 10 seconds is displayed, a moving average of both measures is shown. The reduction in IBI (thus the increase in heart rate) is maximal near the junction, reflecting appraisal of the situation and a building-up of tension during the ride. It should be noted that due to the simulated empty (Dutch) landscape, the lampposts could be spotted well in advance. It is remarkable that elderly drivers' heart rate is faster than the young drivers' heart rate. The increase in IBI at the junction could be indicative of coping with the situation (Lazarus & Folkman, 1984, Matthews, 2001). The 0.10 Hz component shows a similar image, a reduction in variability before the junction denoting an increase in tension and mental effort.

>> FIGs 10 and 11 here

Discussion

In a driving simulator drivers' behaviour was assessed while driving on a road where elements were added and removed systematically. Elements that were added to the asphalt road were a centre line, road markers, edge-lines, and lampposts. There was no other traffic, nor were there any trees or buildings in the landscape that represented a flat rural area. Between subjects 'response set' was manipulated by giving different instructions about the road's speed limit; 60 or 100 km/h.

It was found that increasing guidance by adding elements to the road not always coincides with a higher driving speed; average speed was fairly constant over conditions. Also, some of the elderly drivers got so little speed cues in the 60 km/h and non-delineated road condition, that their driving speed was relatively high (see figure 3, and figure 4 for the sd speed). Although the younger drivers drove faster than the elderly in the 100 km/h condition, even for them 100 km/h was too fast for the curves, their average speed was 90 km/h. Elderly drivers drove on average 75 km/h in the 100 km/h speed limit instruction.

It is obvious that adding painted material to the road surface affected position on that road. While participants drove at a fairly central position on the non-delineated road, adding a centre line and dividing the asphalt into two lanes immediately resulted in drivers driving in their lane, and accordingly driving more towards the road's edge. It was also found that variability in position (SDLP) was reduced when a centre line was added. However, adding more elements did not further reduce SDLP, but resulted in a small increase. A possible account for this effect might be found in the subjective ratings of effort, these ratings decrease with the addition of elements, indicating that tracking may be facilitated. This in turn may have led to adapted criteria for safe driving, or even adapted safety margins. Another explanation may be that driving more towards the centre line coincides with cutting corners, as there was no meeting traffic.

The present study was performed in a driving simulator. The generalisation of results found in a simulator to the real world can be questioned (e.g., Farber, 1999). Validation studies performed have shown that most results from driving simulators have a relation to results found on-the road (Carsten, Groeger, Blana & Jamson, 1997, Kaptein, Theeuwes & Van der Horst, 1996, Törnros, Harms & Alm, 1997). In general relative changes are very resembling and correlate significantly (Freund, Gravenstein, Ferris & Shaheen, 2002). Although this may mean that a driving speed of 100 km/h in the simulator does not have to lead to exactly the same speed on the real road, it does mean that if a decrease of e.g. 20 % in speed in the simulator is found a similar speed reduction can be expected in the real world. The relative change is the same. Also, in the simulator the similar physiological responses that one finds in the real world have been registered (e.g., De Waard, Van der Hulst, Hoedemaeker & Brookhuis, 1999a, b)

Taking all measures into account, the conclusion must be that if there is a shift in driving behaviour between two delineation conditions, it coincides with the change from the non-delineated to the centre-line road conditions. Lateral position control changes, average heart rate changes, and subjective ratings change. At least some information on the road surface seems to be required to drive constant and comfortably. Another remarkable condition is the road where lampposts were added. Although drivers indicate that the road's course is more clear, it did not lead to reduced effort, reduced swerving (SDLP), or increased speed. Actually speed decreased, while variability in speed increased. After the rides it turned out that opinion about this condition differed between participants, some disliked the presence of the lampposts very much while others appreciated the preview on the road's course. Driving speed differs between the two (age) groups; elderly drivers drive slower, but they vary more in speed. Also, when they are implicitly requested to drive faster (by being told that the road has a speed limit of 100 km/h) this leads to higher levels of subjective effort compared with the young drivers. The fact that effects on physiology of the different conditions were only found on average heart rate and not on heart rate variability are likely to be related to restriction of range of sensitivity of this measure (see, e.g., De Waard & Brookhuis, 1997).

In the ghost road scenario it was studied if and how visually distinct road elements can affect expectations about road course. Although the "straight-on" centre-lined road was not interrupted, the lampposts were visually dominantly present in a way that that road could be perceived as the main road. Elderly drivers were more confused than young drivers, and 50% of them took the ambiguous road.

This may be interpreted as an age-related difficulty to disentangle ambiguous environmental cues. The interpretation of these findings can be embedded in visual search and visual distraction research. For instance, in experiments with distracting flanker characters, Zeef and Kok (1993) found that elderly people had more difficulty to ignore the interference from incompatible distractors. Furthermore, Zeef, Sonke, Kok, Buiten and Kenemans (1996) found that the distraction by flankers was more pronounced when the flankers were more similar to the target (i.e., more ambiguity). This effect was largest for the elderly.

Other studies report that elderly more than young participants are unable to suppress saccades to a suddenly appearing stimulus in the peripheral visual field (Nieuwenhuis et al., 2000), or have difficuly in switching task goals (De Jong, 2001). Findings in this respect are related to age-induced reduction in goal generation and goal maintenance (see for an in-depth discussion De Jong, 2001). While these findings came from highly artificial laboratory situations, the present study gives some support from the more natural (although highly controlled) task situation of car driving.

The heart rate data were also quite revealing and show a building up of tension and stress, and a relief after it was over. This relief can especially be seen in the elderly driver group (which was the group who took the "wrong" road more often). It is important to note that visually ambiguous situations can confuse drives, and can lead to hesitant behaviour, perhaps even resulting in dangerous behaviour.

Conclusions

The main shift in behaviour with respect to critical visual information is between the non-delineated and centre-line delineated roads. This is comparable to the minimal line contrast requirements by McKnight et al. (1998). Speed instruction has not been found to have an influence on this threshold, although older drivers drive slower to enable processing of all information. Some visual information such as lampposts may actually be more distracting for elderly drivers than that it helps them, it seems preferable for them to regulate visual input by adapting their driving speed. Elderly drivers were indeed more often confused by the ambiguous road.

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Figure Captions

Figure 1. Simulator (centre-view) snapshot from condition 2 (centre-line only) and 5 (fully delineated plus lampposts). The rearview mirror is inserted in the image.

Figure 2. Ghost road turning to the right at the ambiguous junction

Figure 3. Average speed per section, speed instruction (60 or 100 km/h) and group

Figure 4. Variability in speed (Standard Deviation Speed) per section, speed instruction (60 or 100 km/h) and group

Figure 5. Mean position on the road as measured as distance from the centre of the driver's seat to the road edge. Averages are displayed per section, speed instruction (60 or 100 km/h) and group

Figure 6. Standard deviation of the lateral position (SDLP) per section, speed instruction (60 or 100 km/h) and group

Figure 7. Average self-reported effort (0="no effort", 10="extremely effortful")

Figure 8. Average self-reported clearness of road course (0="not clear at all", 10="very clear")

Figure 9. Average inter-beat-interval (IBI) in heartrate per group and section.

Figure 10. Average inter-beat-interval (IBI) in heartrate per group while approaching the point where the road forks. Each point on the x-axis depicts 10 seconds time increase, while heartrate data are based on 30 s data input.

Figure 11. Heart rate variability: average energy in the 0.10 Hz frequency band (Ln-transformed) while approaching the point where the road forks. Each point on the x-axis depicts 10 seconds time increase, while heartrate data are based on 30 s data input.

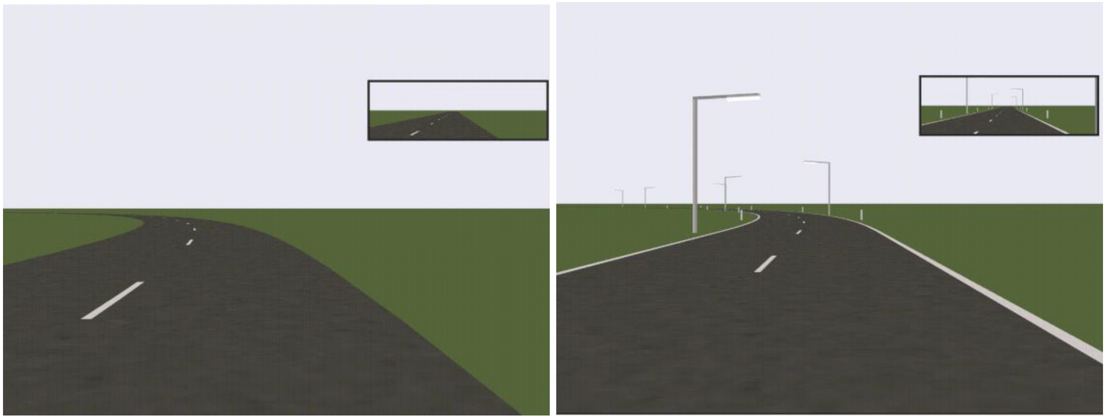
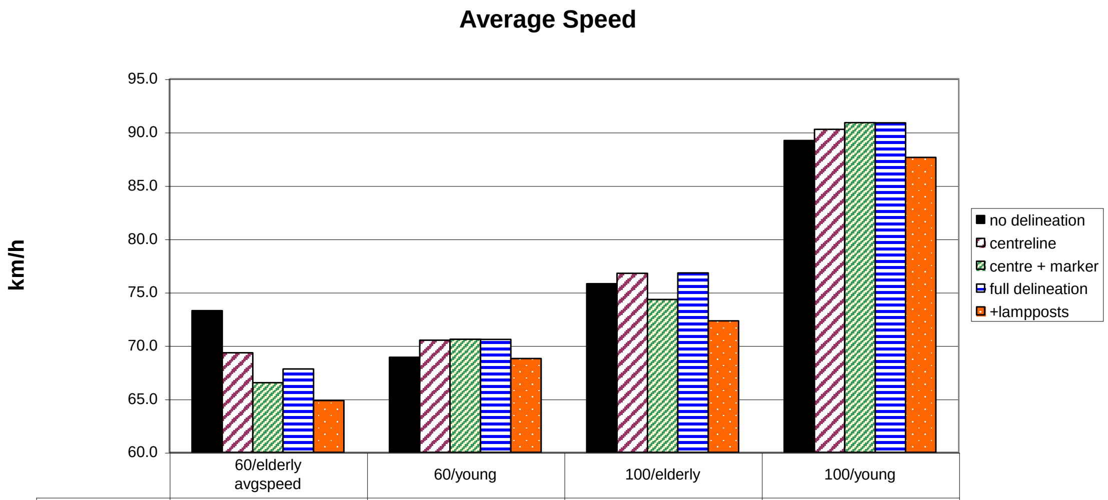


Figure 1 Simulator (centre-view) snapshot from condition 2 (centre-line only) and 5 (fully delineated plus lampposts). The rearview mirror is inserted in the image.

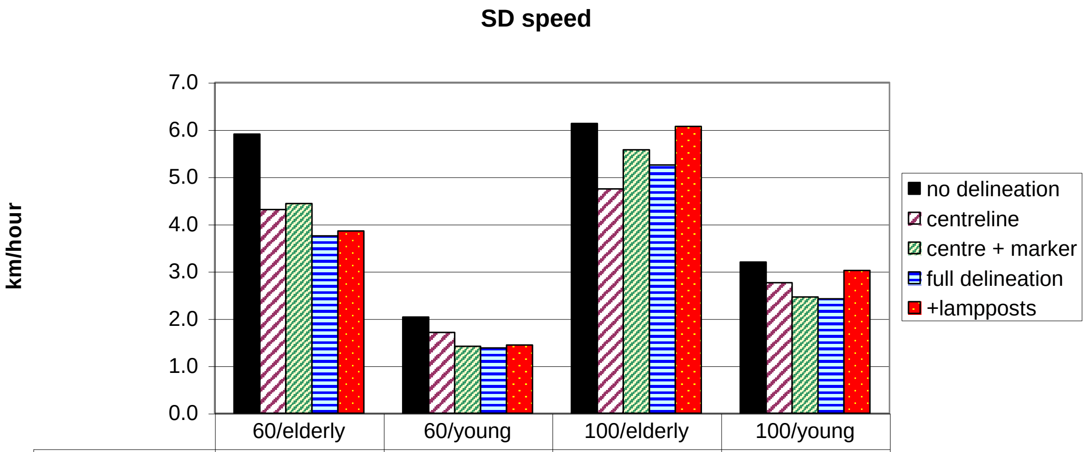
Figure 2: Ghost road turning to the right at the ambiguous junction



	60/elderly avgspeed	60/young	100/elderly	100/young
no delineation	73.3	68.9	75.8	89.2
centreline	69.3	70.5	76.8	90.3
centre + marker	66.5	70.6	74.3	90.9
full delineation	67.8	70.6	76.8	90.9
+lampposts	64.9	68.8	72.3	87.6

group

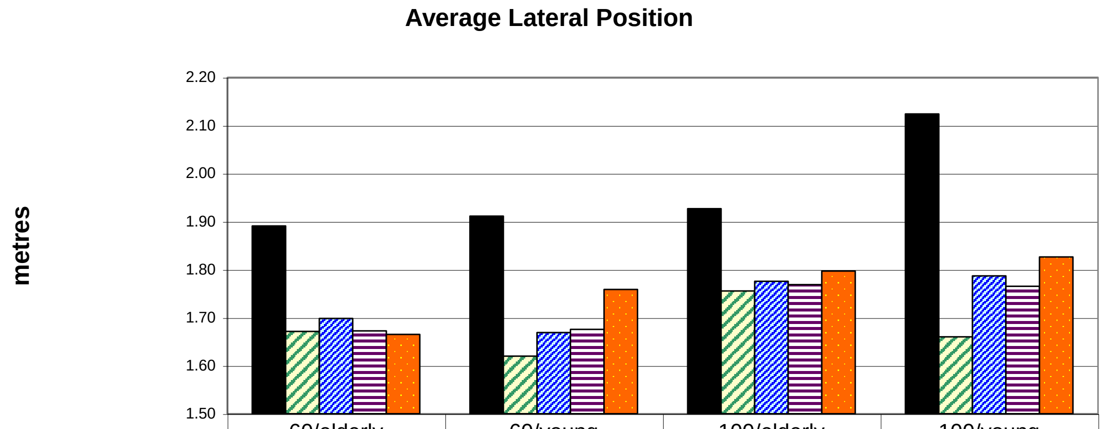
Figure 3. Average speed per section, speed instruction (60 or 100 km/h) and group



	60/elderly	60/young	100/elderly	100/young
no delineation	5.9	2.0	6.1	3.2
centreline	4.3	1.7	4.7	2.8
centre + marker	4.4	1.4	5.6	2.5
full delineation	3.8	1.4	5.3	2.4
+lampposts	3.9	1.4	6.1	3.0

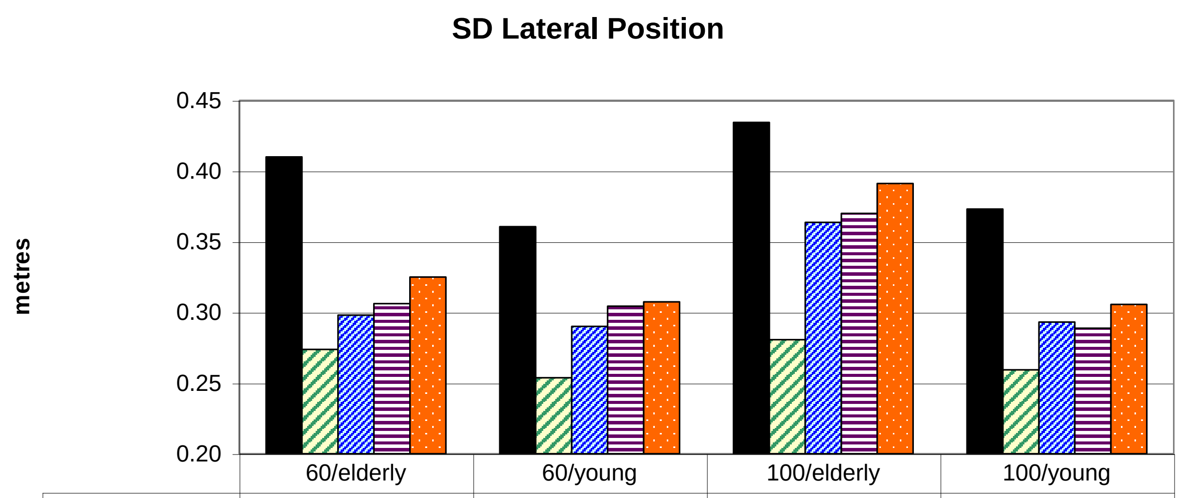
group

Figure 4. Variability in speed (Standard Deviation Speed) per section, speed instruction (60 or 100 km/h) and group



	60/elderly	60/young	100/elderly	100/young
no delineation	1.89	1.91	1.93	2.12
centreline	1.67	1.62	1.76	1.66
centre + marker	1.70	1.67	1.78	1.79
full delineation	1.67	1.68	1.77	1.77
+lampposts	1.67	1.76	1.80	1.83

Figure 5. Mean position on the road as measured as distance from the centre of the driver's seat to the road edge. Averages are displayed per section, speed instruction (60 or 100 km/h) and group



	60/elderly	60/young	100/elderly	100/young
no delineation	0.41	0.36	0.43	0.37
centreline	0.27	0.25	0.28	0.26
centre + marker	0.30	0.29	0.36	0.29
full delineation	0.31	0.30	0.37	0.29
+lampposts	0.33	0.31	0.39	0.31

group

Figure 6. Standard deviation of the lateral position (SDLP) per section, speed instruction (60 or 100 km/h) and group

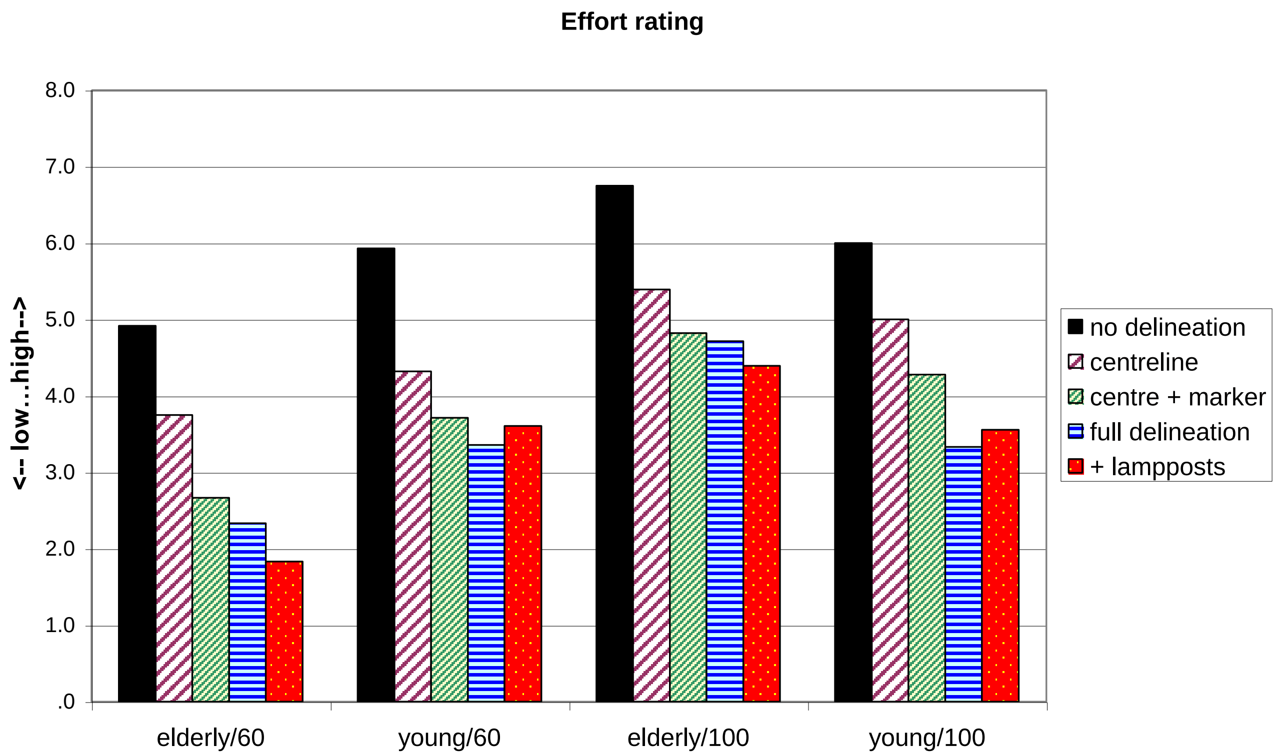


Figure 7. Average self-reported effort (0=”no effort”, 10=”extremely effortful”)

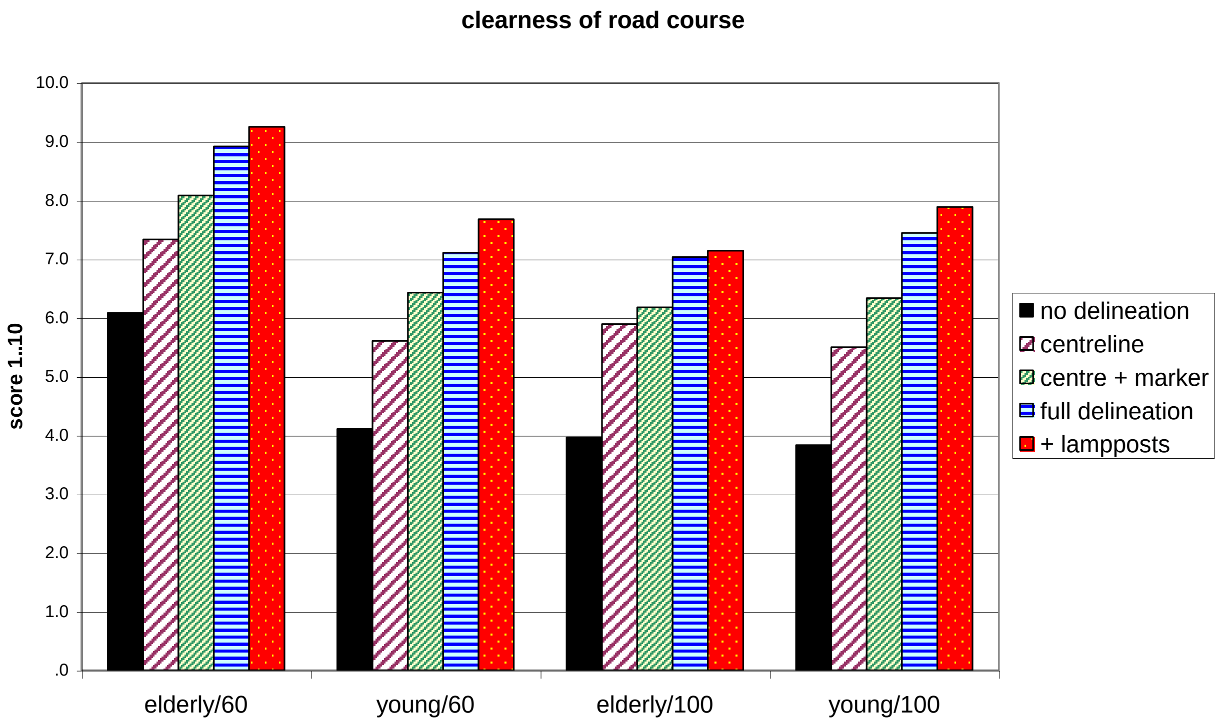


Figure 8. Average self-reported clearness of road course (0=”not clear at all”, 10=”very clear”)

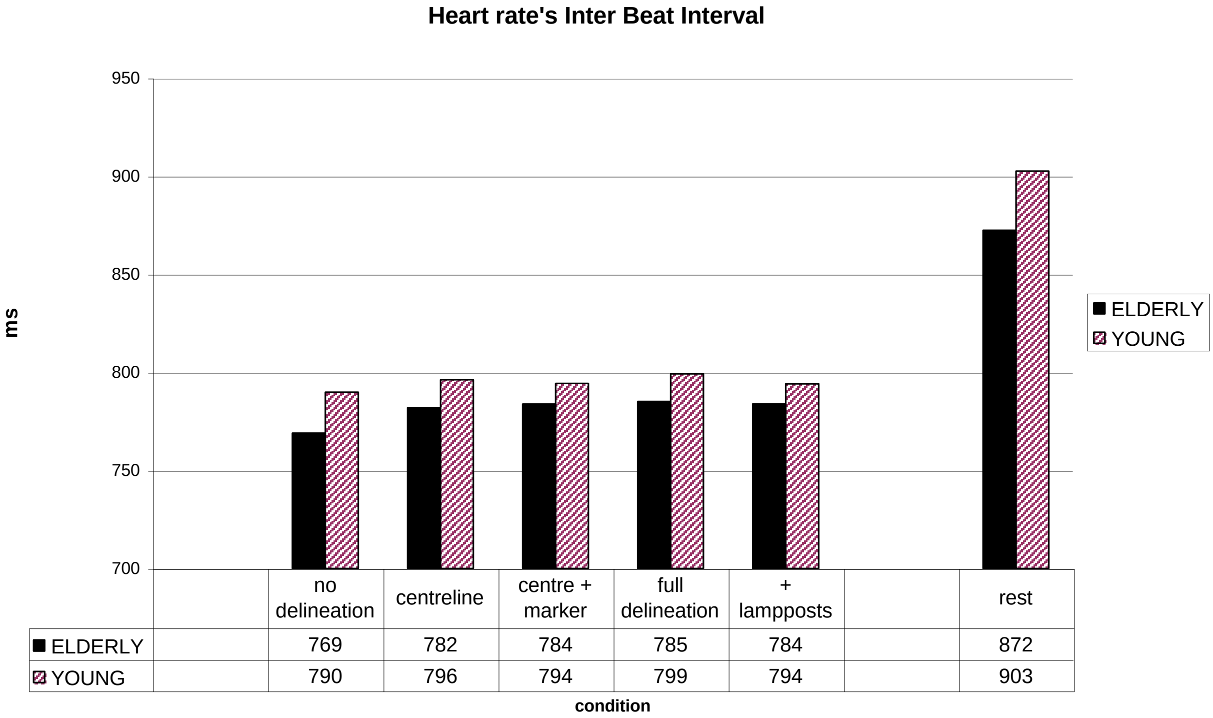


Figure 9. Average inter-beat-interval (IBI) in heartrate per group and section.

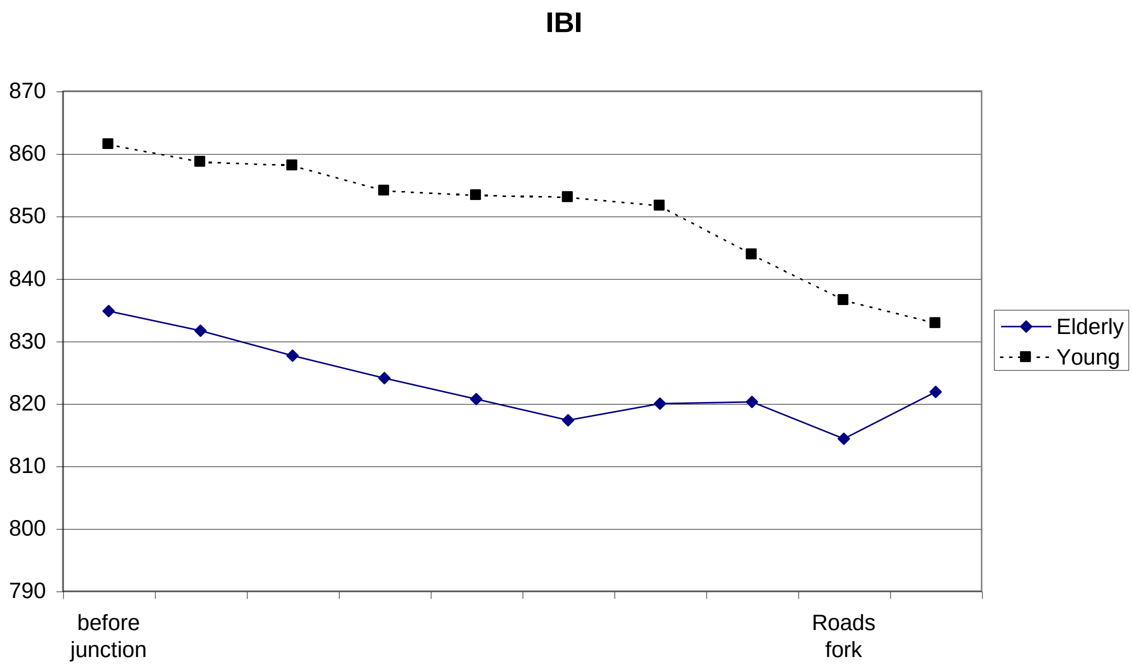


Figure 10. Average inter-beat-interval (IBI) in heartrate per group while approaching the point where the road forks. Each point on the x-axis depicts 10 seconds time increase, while heartrate data are based on 30 s data input.

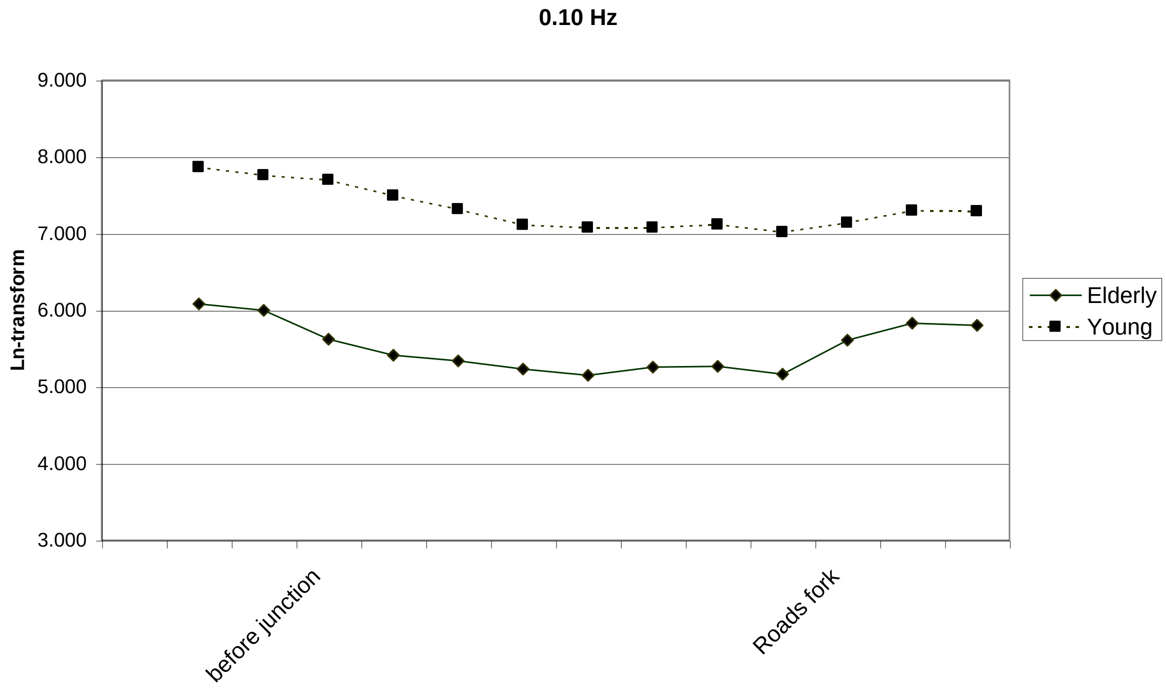


Figure 11. Heart rate variability: average energy in the 0.10 Hz frequency band (Ln-transformed) while approaching the point where the road forks. Each point on the x-axis depicts 10 seconds time increase, while heartrate data are based on 30 s data input.