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Worn windscreens

Simulator study

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FINDING A BETTER WAY

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One traffic safety problem that has been observed in several studies is the wear of the windscreens. The risk of dazzling increases when driving with a worn windscreen, which may have the consequence that the driver does not discover objects or people on the road in front of the vehicle.

The behaviour of 24 drivers has been studied in a driving simulator using three windscreens with different level of usage. To achieve dazzling in the driving simulator a lamp was mounted in front of the windscreen in the simulator. The lamp simulated a setting sun.

When the driver had to make way for an obstacle on the road, this was more difficult with the worn windscreens, despite the lower speed. The drivers discovered the obstacles later, used a harder brake power and took a more powerful action to avoid the obstacle. Altogether this indicates a more risky driving behaviour, in other words decreased traffic safety.

The sight length to a cone was also measured. The results showed that the sight length became shorter with worn windscreen.

When the drivers were asked to express their opinion about the experiment, they assessed both the simulated environment and the driving task as relatively realistic.

Even though this is a simulated situation, with its limitations, the results indicate that driving under dazzling conditions with a worn windscreen has negative effects on driver behaviour.

Keywords:
Simulator study, dazzle, driver behaviour, sight length, windscreen, wear

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Ett trafiksäkerhetsproblem som har uppmärksammats i olika studier är slitage på vindrutor. När vindrutan på ett fordon slits ökar risken för bländning, vilket kan leda till att föraren inte i tid hinner se föremål eller personer som befinner sig på eller vid vägen.

I en simulatorstudie med 24 försökspersoner har förarbeteende vid bländning studerats för vindrutor med olika grad av slitage. För att skapa bländning i simulatorn monterades en lampa framför den främre skärmen i simulatorn. Lampan fick simulera en lågt stående sol.

När förarna var tvingade att väja för hinder på vägen klarade de undanmanövern sämre när de körde med en vindruta som var sliten, trots att de höll en lägre hastighet. Förarna upptäckte hindret senare, bromsade kraftigare och gjorde en häftigare undanmanöver. Detta indikerar ett mer riskfyllt körbeteende. Några förare hann inte alls väja för hindret utan körde på det.

I samband med försöket genomfördes även en siktlängsdsmätning. Resultaten visade att siktlängden minskade vid körning med de slitna rutorna.

Försökspersonerna uppgav att de ansåg att såväl den simulerade miljön som köruppgifterna i simulatorkörningen var relativt realistiska.

Även om detta är en studie i simulatormiljö, med sina begränsningar, kan man konstatera att körbeteendet påverkas negativt vid körning i motljus med sliten vindruta.

Nyckelord:

Simulatorstudie, bländning, förarbeteende, siktsträckor, vindrutor, slitage

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Preface

This study has been funded by the Scandinavian glass trade associations; Swedish Glasbranschföreningen, Danish Dansk Autoglas and Norwegian Bilglassforeningen. Glasbranschföreningen has also provided the windscreens that have been used in the study.

Jimmy Langetun from Glasbranschföreningen has contributed with knowledge about windscreens and windscreen wear.

Stefan Bengtsson from SAMGLAS in Linköping has taken care of the assembly and disassembly of windscreens in the simulator.

For measuring of the wear of the windscreens, Glasbranschföreningen provided a DMO/Iris instrument for measuring of SLI. An additional instrument was borrowed from the division of the Swedish Motor Vehicle Inspection Company in Norrköping; this was a DMO/Iris instrument, as well.

Mats Lidström, VTI, developed the graphics used in the simulator. Laban Källgren, VTI, was responsible for scenario development and Albert Kircher, VTI, constructed the artificial sun.

Janet Yakoub and Kristina Kindgren, VTI, were test leaders during the study and took care of our test subjects.

Mohammad-Reza Yahya, VTI, has analysed all the data from the simulator drives and the questionnaires.

Sven-Olof Lundkvist, VTI, has contributed with knowledge about dazzle problems and measuring of windscreens.

Gunilla Sörensen, VTI, has contributed to the writing of the report.

Gunilla Sjöberg, VTI, edited the report.

The undersigned has been the Project Manager and has contributed to all parts of the work.

I wish to thank everyone who has been committed in various ways to this project and, in particular, those who have volunteered to be test subjects!

I will also thank Andres Veiper, Premium Translation Agency in Estonia, for helping me with the translation from Swedish to English of this report.

Linköping, August 2009

Anne Bolling

Cover: Anne Bolling, VTI and photos.com

Quality review

Review seminar was carried out on 7 September 2009 where Lars Eriksson, VTI, reviewed and commented on the report. Anne Bolling has made alterations to the final manuscript of the report. The research director of the project manager Jonas Jansson examined and approved the report for publication on 29 October 2009.

Kvalitetsgranskning

Granskningsseminarium genomfört 7 september 2009 där Lars Eriksson, VTI, var lektör. Anne Bolling har därefter genomfört justeringar av slutligt rapportmanus. Projektledarens närmaste chef Jonas Jansson har granskat och godkänt publikationen för publicering 29 oktober 2009.

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Summary

One traffic safety problem that has been observed in several studies is the wear of the windscreens. The risk of dazzling increases when driving with a worn windscreen, which may have the consequence that the driver does not discover objects or people on the road in front of the vehicle.

In this simulator study driver behaviour has been studied using three windscreens, one driven 150 000 kilometres, another driven 350 000 kilometres and one unused. The experiment has a within groups design. In this case this means that all 24 test persons drive under each experimental condition, i.e. everyone with each of the three windscreens. The driver passes two obstacles during each drive.

To achieve dazzling in the driving simulator a lamp was mounted in front of the windscreen in the simulator. The lamp simulated a setting sun.

The sight length to a cone was measured. The results showed that the sight length became shorter with a worn windscreen. The difference in sight length between the unused and the most worn windscreen was on average 131 metres (±22 metres), implying a reduction in sight length of approximately 65 percent.

When the driver had to make way for an obstacle on the road, this was more difficult with a worn windscreen. The drivers discovered the obstacles later, used a harder brake power and took a more powerful action to avoid the obstacle, despite the fact that the average speed was decreased with approximately 15 kilometres per hour. Altogether this indicates a more risky driving behaviour, in other words decreased traffic safety.

Some of the drivers were not able to avoid the obstacle at all and hence collided. None of the obstacle passes, while driving with the unused windscreen, led to any collision, but four percent led to a collision while driving with the windscreen used in traffic for 150 000 kilometres and eight percent led to a collision with the windscreen used in traffic for 350 000 kilometres. However, due to the low number of observations there was no point in performing any statistical analysis. Still, the results indicate that driver behaviour and safety margins are severely effected by worn windscreens. Considering that in real traffic these events had been traffic accidents the results are alarming and show that driving with worn windscreens in dazzling conditions can be dangerous.

When the drivers were asked to express their opinion about the experiment, they assessed both the simulated environment and the driving task as relatively realistic.

Even though this is a simulated situation, with its limitations, the results indicate that driving with a worn windscreen has negative effects on driver behaviour. The problem may be even greater in real traffic since there are other factors, such as mud and rain that effect sight and dazzle. Already with a windscreen used during 150 000 kilometres the driver behaviour is negatively effected. Since there are probably a considerable

amount of vehicles in traffic with windscreens that has been used 150 000 kilometres or more, the problem with worn windscreens should be taken seriously.

Slitna vindrutor – simulatorstudie

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Sammanfattning

Ett trafiksäkerhetsproblem som har uppmärksammats i olika studier är slitage på vindrutor. När vindrutan på ett fordon slits ökar risken för bländning, vilket kan leda till att föraren inte i tid hinner se föremål eller personer som befinner sig på eller vid vägen.

I denna simulatorstudie har förarbeteende vid bländning studerats för vindrutor med olika grad av slitage. Tre vindrutor ingick i studien – en oanvänd, en som hade använts i 150 000 kilometers körning och en som hade använts i 350 000 kilometers körning. Försöket har en inomgruppsdesign. Det innebär att alla 24 försökspersoner får köra med varje betingelse, i detta fall tre gånger, en gång med varje vindruta. Förarna fick passera två hinder vid varje körning.

För att skapa bländning i simulatorn monterades en lampa framför den främre skärmen i simulatorn. Lampan fick simulera en lågt stående sol.

Vid försöket genomfördes en mätning av siktlängd. Resultaten visade att siktlängden minskade vid körning med de slitna rutorna. Skillnaden i upptäcktsavstånd mellan bästa och sämsta vindrutan var 131 meter (±22 meter), vilket innebar en sänkning med i genomsnitt cirka 65 procent.

Vid undersökning av vad som hände när förarna var tvingade att väja för hinder på vägen ser vi att man klarade undanmanövern sämre när man körde med en vindruta som var sliten. Förarna upptäckte hindret senare, bromsade kraftigare och gjorde en häftigare undanmanöver, trots det faktum att de hade sänkt sin genomsnittliga hastighet med cirka 15 kilometer i timmen. Dessa resultat indikerar ett mer riskfyllt körbeteende eller med andra ord lägre trafiksäkerhet.

Några förare hann inte alls väja för hindret utan körde på det. Ingen av hinderpassagerna vid körning med den oanvända vindrutan ledde till kollision, medan fyra procent av passagerna ledde till kollision vid körning med den näst mest slitna vindrutan och åtta procent ledde till kollision vid körning med den mest slitna vindrutan. Med tanke på att detta i verklig trafik kunde ha varit trafikolyckor, pekar resultaten på att det kan medföra en stor olycksrisk att köra med slitna rutor i så svåra förhållanden som motljus. På grund av det låga antalet observationer bedömdes det inte vara meningsfullt att statistiskt testa dessa resultat, men de ger ändå en indikation om att körbeteendet och säkerhetsmarginalerna påverkas negativt av de slitna rutorna.

Försökspersonerna uppgav att de ansåg att såväl den simulerade miljön som köruppgifterna i simulatorkörningen var relativt realistiska.

Även om detta är en studie i simulatormiljö, med sina begränsningar, kan man konstatera att körbeteendet påverkas negativt vid körning i motljus med sliten vindruta. I verklig trafik är det dessutom många fler faktorer som kan påverka sikt och bländning, såsom smuts och väta. Det finns därför en risk att effekten på körbeteendet vid körning i verklig trafik kan vara avsevärt större än vad som har kunnat mätas i denna studie.

Redan med en vindruta som har använts i 150 000 km har denna studie påvisat negativa effekter på körbeteendet. Troligen finns det en ansenlig mängd fordon i trafik med vindrutor som har använts i 150 000 km eller mera, vilket gör att problemet bör tas på allvar.

1 Background

Particles in the air expose the windscreens of the vehicles to significant strain and cause a blasting effect on the glass. Windscreens are also exposed to extensive mechanical wear, above all, from the windscreen wipers, as a result of which the light can be refracted incorrectly, thereby impairing visibility.

One traffic safety problem that has been observed in several studies is the wear of the windscreens. The risk of dazzling increases when driving with a worn windscreen, which may have the consequence that the driver does not discover objects or people on the road in front of the vehicle. Dazzling is caused by the diffusion of light through the windscreen, for example, from the setting sun or from oncoming vehicles during the dark hours. The effect of the dazzling varies depending on the degree of wear of the windscreen.

The Swedish Road Administration establishes on its website that visibility is one of the most important factors for driving safety. Furthermore, it says that “Dirty and worn windscreens can significantly reduce visibility. Very worn windscreens can reduce the sight length by up to 20%” (The Swedish Road Administration, 22.03.2009). A shorter sight length leads to later discovery of obstacles and, as a result, the driver may not manage to brake in time. This, in turn, may lead to decreased capability to avoid a potential accident.

One of the studies carried out by VTI analyses the distance at which obstacles are discovered on the road while driving in the dark (Lundkvist & Helmers, 1993). The study showed a connection between the wear of the windscreen and the distance at which such obstacles are discovered. In the event of oncoming traffic during the dark hours a driver with a windscreen which has been driven more than 100,000 kilometres may have a sight length which is more than 10% shorter than if the windscreen had been new. If the driver, moreover, suffers from visual impairment (visual acuity of 0.5), the loss of sight length is estimated at 25%. Approximately one in every 20 motor vehicles in traffic is estimated to have been driven 100,000 kilometres or more.

2 Purpose

The purpose of the work has been to study the effect on driver behaviour when driving with worn windscreens. Previous studies at VTI have studied, above all, sight length in the event of dazzling from oncoming motor vehicles during dark hours. This study, however, analyses how dazzling caused by simulated sunlight influences driver behaviour and drivers' sight length. Mainly variables which influence driving safety are registered. The primary objective of the measurement of sight length is to enable comparisons with other studies.

3 Method

To be able to measure the effect of wear on windscreens, a simulator study has been conducted. VTI's driving simulator III, which is equipped with a passenger car cabin and an advanced movement system, is used for this purpose (VTI, 19.02.2009). The driving simulator shows the surroundings of the driver on three main screens, as well as in three back mirrors. A shaking table, which simulates contact with the roadway, is situated under the cabin. The shaking table is placed on a track which makes it possible for the whole simulator cabin to move sideways. The cabin can even tilt in several directions. In this way, lateral forces influencing the driver are simulated. As a result of all this, the experience of the driver on the road becomes more true to reality.

Dazzling is caused by the diffusion of light through the windscreen. The dazzling can vary depending on the degree of wear of the windscreen. We are studying how this dazzling affects driver behaviour on the road, above all, by measuring several variables that affect driving safety.

In order to achieve dazzling in the simulator, a lamp was mounted in front of the front windscreen in the simulator. The lamp was supposed to simulate a low sun, see Appendix 3. The glare shields were lowered in order to prevent direct dazzling from the lamp. Figure 1 shows a photograph taken with dazzling in the simulator, as seen from the driver's perspective.

Figure 1 Driver's perspective with dazzling in the simulator. Photograph: VTI.

The experiment was conducted during the spring of 2009.

3.1 Experimental setup

Three different windscreens were used in the study:

0 = unused windscreen

15 = used for 150,000 km

35 = used for 350,000 km

The unused windscreen (0) was used as reference. A windscreen from a taxi, which had travelled 350,000 kilometres on the stretch Arlanda–Stockholm, was to represent a very worn windscreen (35). In order to represent a more normally worn windscreen, a windscreen driven 150,000 kilometres (15) was selected. The two used windscreens were provided by Glasbranschföreningen.

The windscreens were cleaned up carefully on the inside and outside. In order to assess how worn the windscreens were, SLI (Stray Light Index, defined in German standard DIN 52298), which gives a value of how the light is diffused through the windscreen, was measured. An instrument for measuring of SLI was provided by Glasbranschföreningen (a DMO/Iris instrument). The first measurements which were carried out resulted in very substantial variations in the measuring results and this is why an additional instrument was borrowed from the division of the Swedish Motor Vehicle Inspection Company in Norrköping (a DMO/Iris instrument). This instrument also gave considerable variations for each windscreen but repeated measurements, nevertheless, showed differences in the SLI values between the three windscreens. Windscreen 0 had a SLI value of approximately 0.05, windscreen 15 SLI of approximately 0.8 and windscreen 35 SLI > 1.

Test subjects

A total of 24 test subjects from VTI's register of drivers who had expressed an interest in participating in VTI experiments took part in the study. The requirements that were placed on the test subjects were that they did not use lenses or glasses during driving. The drivers were supposed to have had a driver's licence for at least four years. Both men and women had to be represented. The objective was to achieve diversity in terms of age and driving experience.

The 24 test subjects were between 23 and 64 years old. They drove between 5,000 and 60,000 kilometres every year and had had their licences for between 4 and 46 years. The number of men was 13 and the number of women 11.

A fee of SEK 500 was paid to each test subject.

Description of procedure

The test subjects were called on the telephone and received brief information about the experiment and when it was going to be held. On arrival to VTI, each person was asked to read a participant instruction, see Appendix 1. Afterwards, they had to certify that they had been informed of and accepted the conditions of the experiment, see Appendix 2.

The experiment began with a training drive for approximately 10 minutes in the simulator for each test subject so that they could get used to the simulator environment. The training was conducted without dazzling sunlight and when the training was finished, the artificial sun was lit. The first part of the experiment started straight after this, i.e., the test subjects drove the first drive. After the first drive, the test persons got out of the simulator in order to reply to the first part of the follow-up questionnaire which contained a part on how they assessed themselves as drivers and a part on how worn they experienced the windscreen to be and how safe they experienced it was to drive with this windscreen, see Appendix 4. In connection with this, a break was held. During the break, the windscreen in the simulator was replaced according to the experimental scheme that had been set up in advance, see Table 1. When the windscreen was replaced, the test subjects drove the second drive. Then, the test subjects were asked to answer questions about their experiences of driving with this windscreen and another break was held, while the windscreen was being replaced. Then, the third drive was carried out and the last questions about the last windscreen were finally answered.

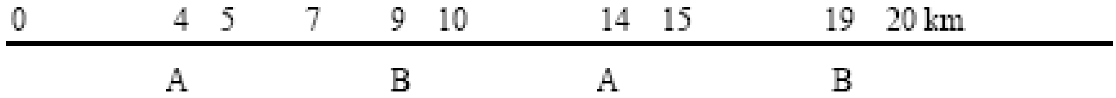
Each drive took approximately 10 minutes and the total time for each test person was approximately two hours.

Experimental setup

The test has a 3x2 setup, with three different windscreens and two different obstacles. A within-group design was used in the experiment. This means that all test subjects drive under all conditions. In this case, this means that all test subjects drove three times, one with each windscreen, and that both obstacles were passed during each drive.

A car with automatic transmission was used in the experiment. The test subjects were instructed to drive as they would normally drive under corresponding conditions in real traffic. A road section of approximately 10 kilometres was re-created in the simulator. The road was nine metres wide and had a speed limit of 90 kilometres per hour. It was surrounded by forest. Obstacles were set up in two places by the side of the road. A passenger car (A) stood by the roadside after 4 kilometres. An excavator (B) was placed by the roadside after 9 kilometres. The passenger car (A) was more clearly visible against the background than the excavator (B). Both obstacles required an evasive manoeuvre. The road section was repeated once, which resulted in a total available distance of 20 kilometres.

The drives were designed in such a way that the drivers had to pass each obstacle once during each drive. The order of the obstacles and the distance to them varied in order to reduce the risk of the test subjects learning where the obstacles were. There was oncoming traffic which occured in predetermined places. Figure 2 shows a sketch of how the three drives were divided across the 20 kilometres.



Drive

1 Start----------------------------End

2 Start--------------------------------End

3 Start------------------------------------End

Figure 2 Sketch of road stretches and position of obstacles.

As mentioned the road section from 0 to 10 km was repeated from 10 to 20 km. In this way, obstacle A occurs at a distance of both 4 and 14 km.

The first drive started at a distance of 7 km and ended at 15 km, which is demonstrated by figure 2.

The second drive started at a distance of 0 km and ended at 10 km.

The third drive started at a distance of 5 km and ended at 15 km.

This order was the same for all test subjects.

Each drive with the different windscreens was concluded with a measurement of the sight length.

The measurement of the sight length was carried out on a completely straight nine-meter-wide road without other traffic. The test subjects were then instructed to drive at 40 km/h and press a response meter button as soon as they discovered an orange cone placed on the hard shoulder.

The simulator experiment was carried out with a balanced order of the windscreens. This means that each windscreen was used just as many times during the first drive as during the second and third drive. This resulted in a total of six different test orders. Four test subjects were assigned to each test order. Table 1 shows the order in which the three windscreens were used for the respective test subject. The table designates the unused windscreen with 0, the one driven 150,000 km with 15 and the one driven 350,000 km with 35.

Table 1 Order of windscreens for each test subject.

	Test order, windscreens		
Test subject	First	Second	Third
FP 1, 2	35	15	0
FP 3, 4	0	35	15
FP 5, 6	15	0	35
FP 7, 8	35	0	15
FP 9, 10	15	35	0
FP 11, 12	0	15	35
FP 13, 14	35	15	0
FP 15, 16	0	35	15
FP 17, 18	15	0	35
FP 19, 20	35	0	15
FP 21, 22	15	35	0
FP 23, 24	0	15	35

Effect measurements

A large amount of data from each drive is registered in the simulator. The data which has been used in this study refers, above all, to speed, braking, movements of the steering wheel and position on the road.

In connection with the measuring of the sight length, the distance between the orange cone and the place where the test subject has pressed the response meter button is analysed.

For each test subject and drive two average speeds are measured. The first one refers to a stretch before obstacle A and the second one to a stretch before obstacle B.

Several different parameters for how the test person has passed the obstacle are analysed in connection with the events. For those who have braked in connection with the obstacle, we analyse how strongly they braked and at which position they began to break. In addition, we study when and how the test subjects evaded the obstacles using the following two criteria: maximum steering angle and maximum lateral acceleration. Here we also examine how much to the left the test subjects have swerved and at which speed the obstacle is passed. Finally, we calculate at which distance the driver discovers the obstacle and acts by braking/evading. The number of drivers who collide with the obstacle are also registered.

The drivers' subjective experiences of the experiments have been analysed on the basis of their survey answers.

Analyses

Data from the simulations have been analysed using SPSS statistical software, version 17.

Differences in the effect measurements between the drives with the different wind-screens have been analysed using T tests and pair tests. As the T tests and pair tests, with a few exceptions, gave the same result, we have chosen to report only the results from the T tests. In order to be able to choose a suitable T test, it was tested if the variables had the same variance. This was done using F tests.

A significance level of 5% has consistently been used.

4 Results

This section describes the results of driving with a simulator equipped with three different windscreens. The following designations are used:

- Windscreen 0 which has not been used in traffic
- Windscreen 15 which has been driven approximately 150,000 km in traffic
- Windscreen 35 which has been driven approximately 350,000 km in traffic.

4.1 Exclusions

The experiment included 24 test subjects, each of whom conducted 3 simulator drives, i.e., a total of 72 simulator drives. During the registration of the data, one drive was excluded: the first drive for test subject 21. The exclusion concerns only the drive with the windscreen which has been driven 150,000 km in traffic. The drop-out has not been compensated.

All test subjects filled out the included questionnaire.

4.2 Sight length

The distance at which an orange cone was discovered while driving at 40 km/h was measured after each drive. Experiences from previous studies have shown that people discover objects later when driving in a simulator than when driving in real traffic. One of the reasons for the differences is the poorer contrast ratio in the simulator. This is why the relative difference between different windscreens is a better criterion than absolute values. The difference in sight length between windscreen 0 and windscreen 15, between windscreen 0 and windscreen 35 and between windscreen 15 and windscreen 35 is calculated. The average values and standard deviations for these differences are calculated for the whole group of test subjects, see Table 2.

Table 2 Distance upon discovery of a cone for three different windscreens (0=unused; 15=driven 150,000 km; 35=driven 35,000 km). Average value and dispersion for distances and differences in distance between windscreens.

	Distance (metres) windscreen 0	Distance (metres) wind-screen 15	Distance (metres) wind-screen 35	Diff wind-screen 0–15	Diff wind-screen 0–35	Diff wind-screen 15–35
Average value	200	91	69	109	131	22
Standard deviation	54	30	22	57	51	26
Variance	2 944	875	466	3 257	2 591	663
Minimum	82	34	25	1	29	-31
Maximum	323	159	101	247	285	82
No of test subjects	23	23	23	23	23	23
Conf. int. (95%)	±23	±13	±9	±25	±22	±11

The table indicates that the cone was discovered at an average distance of 200 metres (±23 metres) with the best windscreen (0). With windscreen 15, the distance shrank to 91 metres (±13 metres) and with windscreen 35 to 69 metres (±9 metres). Thus, the difference in sight length between the best and worst windscreen was 131 metres (±22 metres), i.e., the sight length, on average, became 65% shorter. The differences in sight length between the test subjects were big. This is indicated by high values of statistical dispersion for the sight length where, for example, the minimum value for windscreen 0 was 82 metres, whereas the maximum was 323 metres.

Figure 3 shows the average sight length for each windscreen and differences in the average value between the windscreens. The confidence interval for the average values and the differences is indicated, as well.

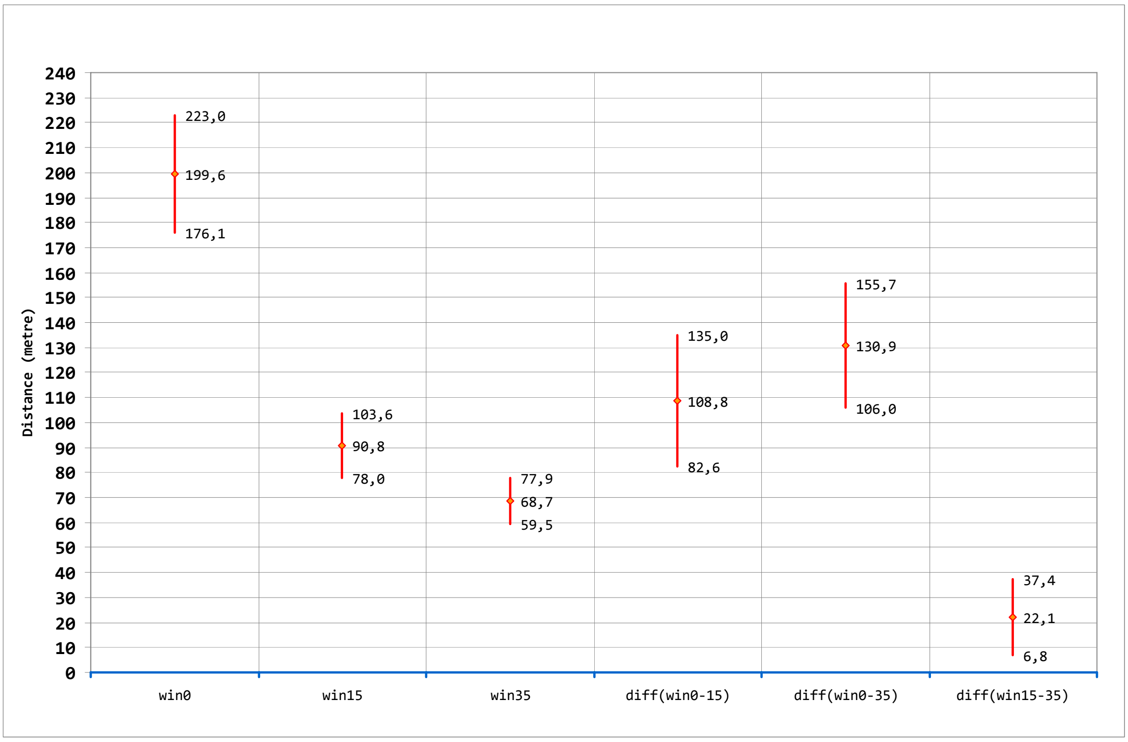


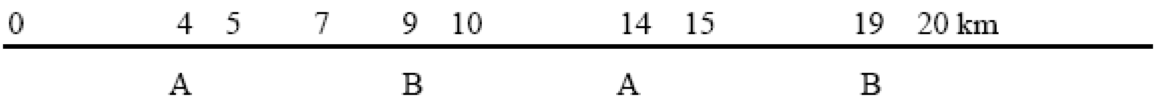
Figure 3 Average values for the distance to the orange cone with windscreen 0, 15 and 35, respectively, and differences in the average value between the windscreens (including the confidence interval for the average values and the differences).

The figure indicates, among other things, that the difference in sight length between the best and the worst windscreen is between 106.0 and 155.7 metres, with a confidence interval of 95%.

4.3 Average speed

The average speed over two stretches has been calculated for each person and each drive. The first stretch is situated before the first obstacle and the second stretch before the second obstacle. The stretches have been chosen so that the speed during the stretch is not affected by the start, end or any of the obstacles.

Figure 4 shows a sketch of the locations for the different stretches (marked with x), for which average speed has been calculated.



1 Start--------------------------------End

xx xxxxxx

2 Start------------------------------------End

xxxx xxxxxxx

3 Start--End

xxxxx xxxxxx

Figure 4 Sketch of stretches for calculation of average speed (marked with x).

For the first drive, which starts at 7,000 metres, the first average speed is calculated for the stretch from 7,800 to 8,300 metres (before obstacle B at 9,000 m). The second average speed is calculated for the stretch from 11,000 to 13,000 metres (before obstacle A at 14,000 metres).

For the second drive, which starts at 0 metres, the first average speed is calculated for the distance from 1,000 to 2,500 metres (before obstacle A at 4,000 m). The second average speed is calculated for the stretch from 4,500 to 7,500 metres (before obstacle B at 9,000 metres).

For the third drive, which starts at 5,000 metres, the first average speed is calculated for the stretch from 6,000 to 8,000 metres (before obstacle B at 9,000 m). The second average speed is calculated for the stretch from 11,000 to 13,000 metres (before obstacle A at 14,000 metres).

The average speed and differences in average speed before obstacle A are reported in Figure 5, together with a confidence interval for the measurements.

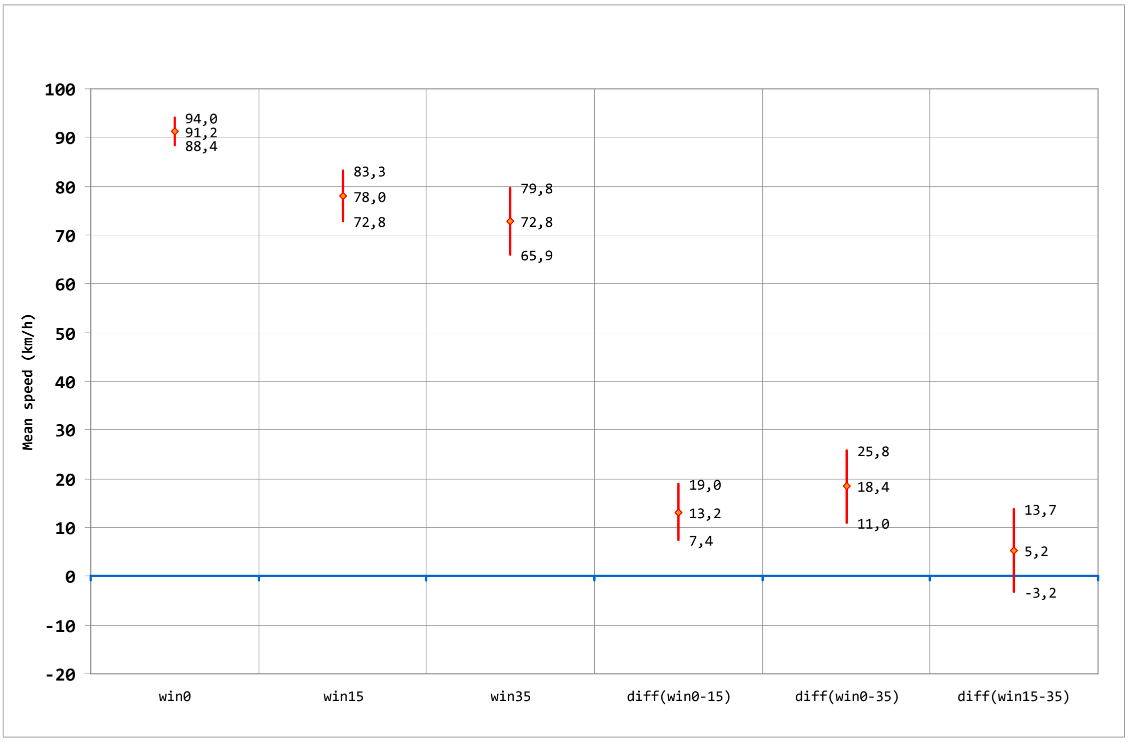


Figure 5 Average speed and difference in average speed before obstacle A for wind-screens 0, 15 and 35 and confidence interval for the average speed and differences.

The average speed and differences in average speed before obstacle B are reported in a corresponding way in Figure 6, together with a confidence interval for the measure-ments.

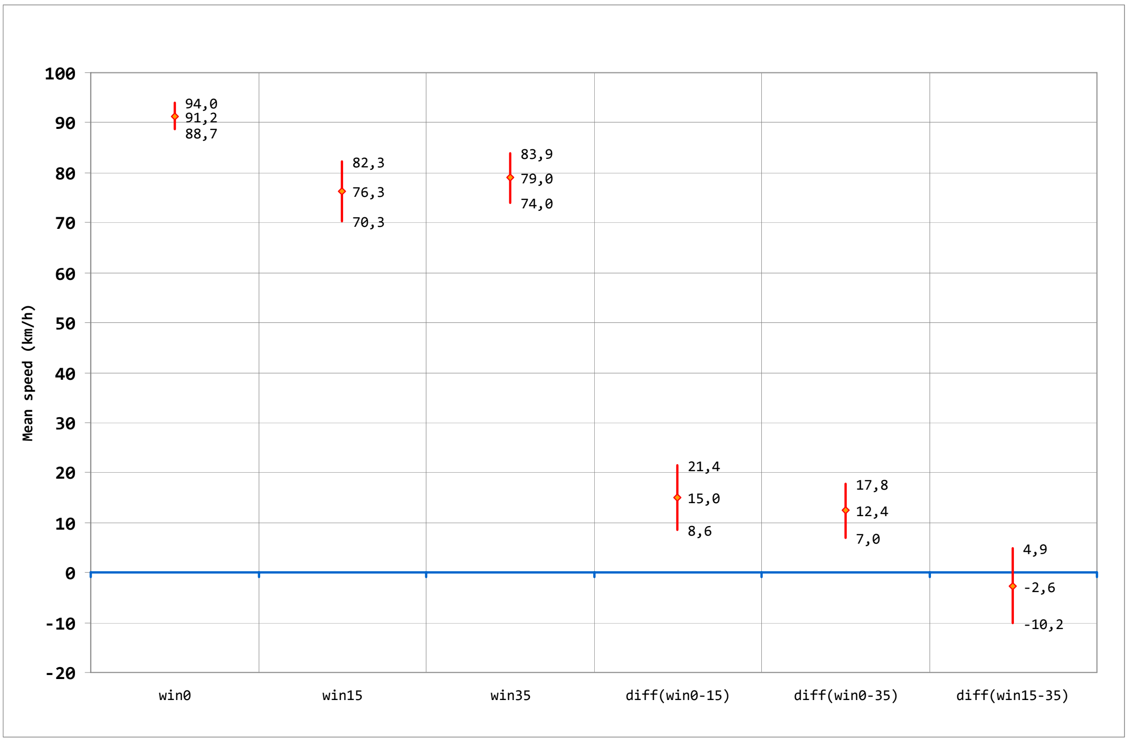


Figure 6 Average speed and difference in average speed before obstacle B for windscreen 0, 15 and 35 and confidence interval for the average speed and differences.

The two figures show that the average speed was 91.2 km/h and 91.4 km/h, respectively, when driving with windscreen 0, but 78.0 and 76.3 km/h when driving with windscreen 15, and 72.8 and 79.0 km/h when driving with windscreen 35. The reduction in average speed when driving with windscreen 15 compared to windscreen 0 was 13.2 and 15.0 km/h, respectively. The corresponding reduction when driving with windscreen 35 compared to windscreen 0 was 18.4 and 12.4 km/h, respectively. These differences were statistically significant on the level of 5%. The difference between driving with windscreen 15 and 35 was not statistically significant.

As a whole, the results show that the drivers reduce their speed by approximately 15 km/h when they are driving with a worn windscreen compared to when driving with an unused windscreen.

4.4 Distance to obstacle when taking action

When the test subjects came near obstacles on the road, some of them braked and took evasive action, others released the gas and took evasive action, but there were also those who did not manage to avoid the obstacle and instead collided with it. For most test subjects, it is possible to determine where they have initiated an action but for some test subjects, it is more difficult to decide at which point the obstacle has started to affect their driving. The place where the action was initiated has been estimated manually and the distance from this position to the obstacle has been calculated. Figure 7 shows the distance to obstacle A on initiating an action in the form of an average value, including the difference between the windscreens and confidence interval for these measurements.

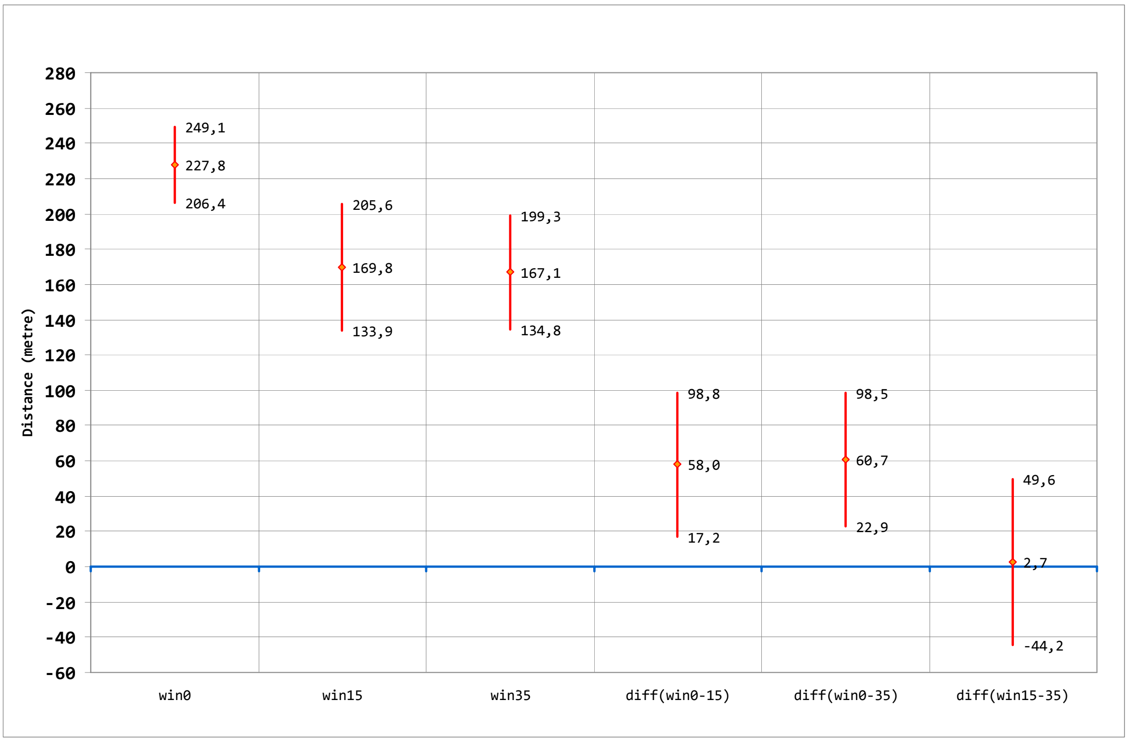


Figure 7 Distance to obstacle A when taking action. Average value, including difference between windscreen and confidence interval for these measurements.

The distance to obstacle B when taking an action is displayed in a corresponding way in Figure 8.

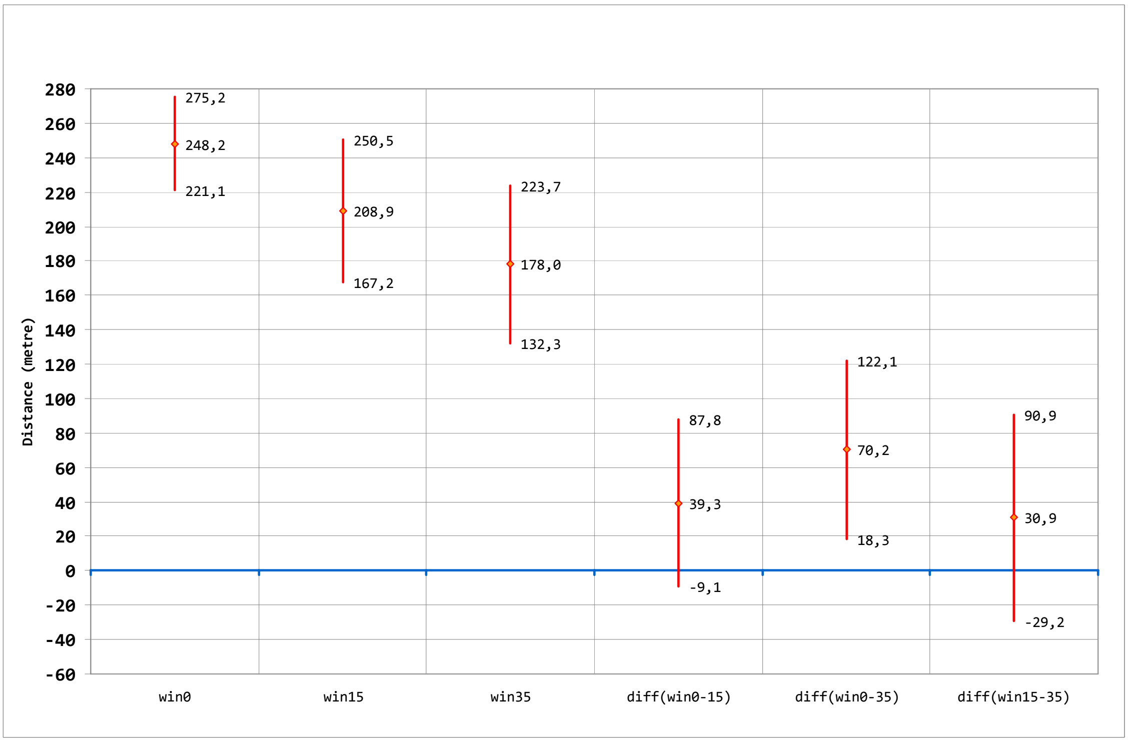


Figure 8 Distance to obstacle B when taking action. Average value, including difference between windscreen and confidence interval for these measurements.

The results show that drivers take a later action – brake or avoid because of an obstacle –when they drive with worn windscreens. The two figures indicate that the average distance to both obstacles when taking an action during a drive with windscreen 0 is 228 and 248 metres, respectively. With windscreen 15, the distance is 170 metres and 209 metres and with windscreen 35, the distance is 167 metres and 178 metres, respectively. The difference in distance when driving with windscreen 0 compared to when driving with windscreen 15 is 58 and 39 (not sign.) metres, respectively. The difference for windscreen 0 compared to windscreen 15 is 61 and 70 metres, respectively. For windscreen 15 compared to windscreen 35 there are no statistically significant differences.

4.5 Braking before obstacles

Part of the drivers braked before the obstacles. The measurements analysed in connection with these brakings include the maximum braking power that was used and where the braking was initiated. In addition, the number of drivers who braked at each obstacle has been calculated.

With windscreen 0, a total of 16 and 11 drivers, respectively, braked before the two obstacles. With windscreen 15 a total of 11 and 13 drivers, respectively, braked and with windscreen 35 there were 12 and 14 drivers, respectively, that braked. In other words, approximately the same number of drivers braked regardless of windscreen. Figure 9 shows the average distance to obstacle A where the drivers start to brake.

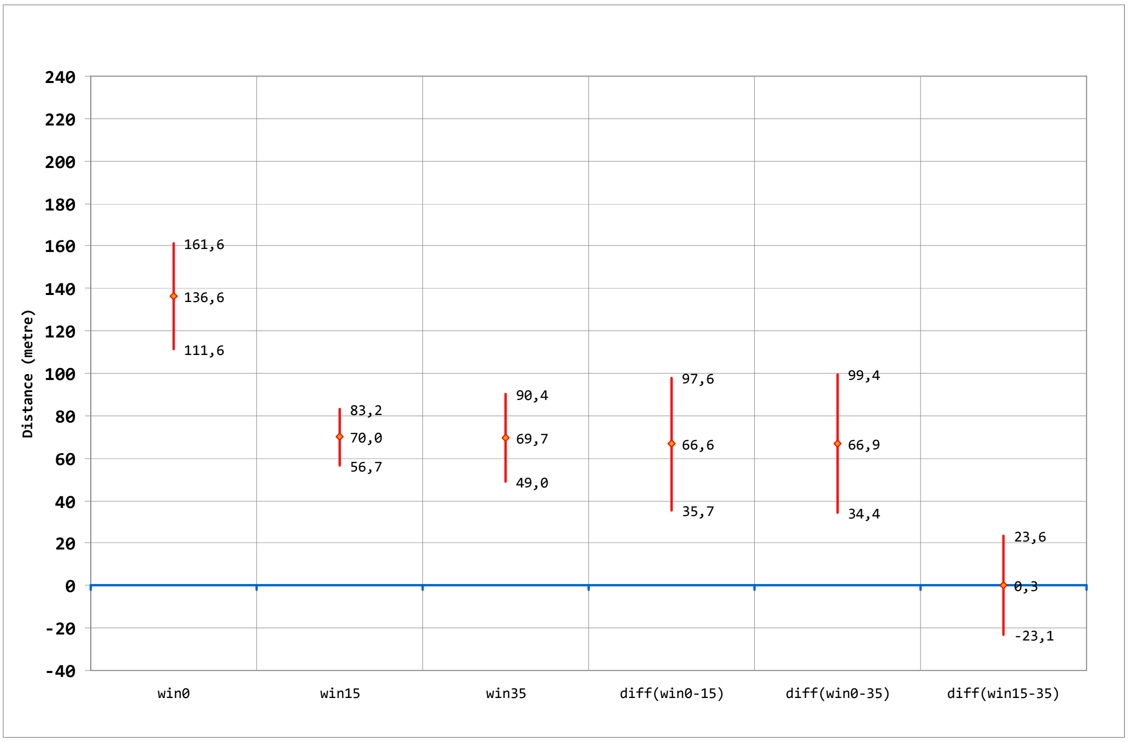


Figure 9 Average distance to obstacle A when the drivers started to brake.

Figure 10 shows the corresponding measurements for obstacle B.

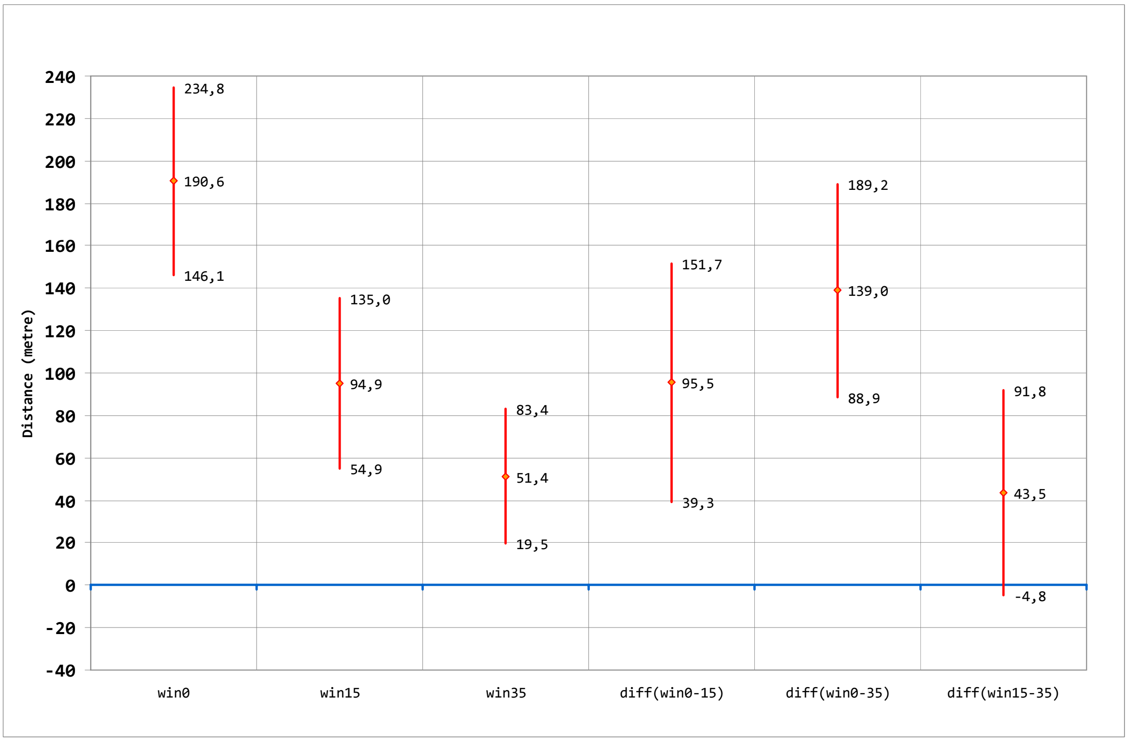


Figure 10 Average distance to obstacle B when the drivers started to brake.

The two figures indicate that the distance to the obstacles when the drivers started to brake varies. The distance was 137 and 190 metres, respectively, with windscreen 0, 70 and 95 metres, respectively, with windscreen 15, and 70 and 51 metres, respectively, with windscreen 35. The difference in distance to the obstacle between windscreen 0 and windscreen 15 was 67 and 96 metres, respectively; the difference between windscreen 0 and windscreen 35 was 67 and 139 metres, respectively. The difference between windscreen 15 and windscreen 35 was not statistically significant.

Thus, the results show that those who brake before the obstacle brake later with worn windscreens and that the differences are larger with obstacle B.

The maximum braking power during the braking process before the obstacles varied, which is indicated by Figure 11 and Figure 12.

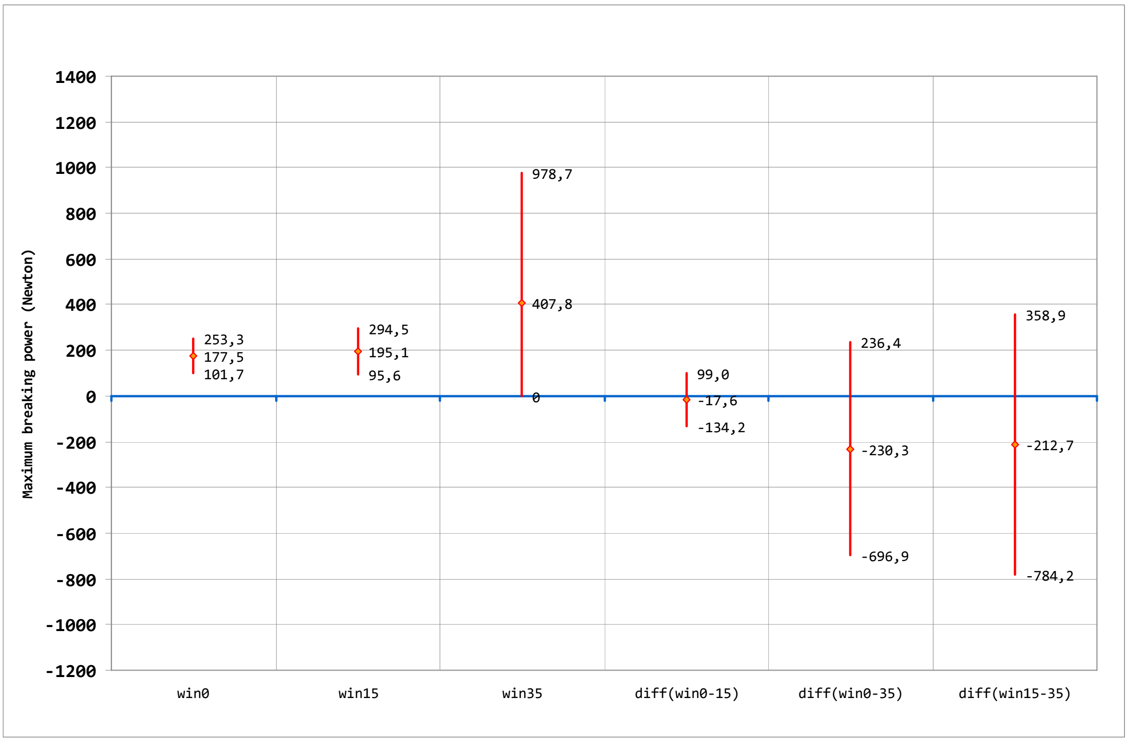


Figure 11 Maximum braking power before obstacle A. Average value, differences between windscreens and confidence interval for these measurements.

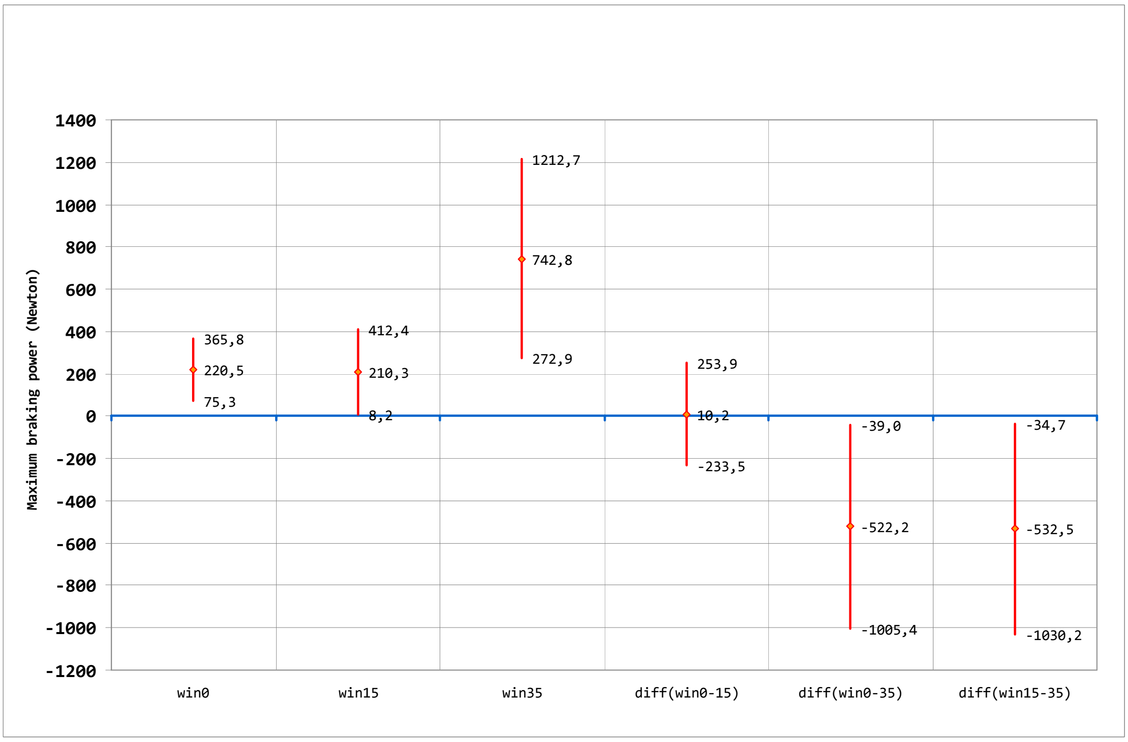


Figure 12 Maximum braking power before obstacle B. Average value, differences between windscreens and confidence interval for these measurements.

The difference in average maximum braking power between drives with the different windscreens was not significant for obstacle A. For obstacle B, the difference between windscreen 0 and windscreen 15 was not significant, either. The difference between windscreen 0 and windscreen 35 was 522 Newton, whereas the difference between windscreen 15 and 35 was 533 Newton.

Only with obstacle B and with windscreen 35, the maximum braking power differed significantly from the results from the other windscreens. There is a consistent tendency, however, that a more worn windscreen leads to later discovery of the obstacle and that the drivers must brake more strongly in order to be able to avoid the obstacle.

4.6 Maximum steering wheel angle and lateral acceleration before obstacles

In order to obtain measurements of how the driver has evaded the obstacles, the maximum angle of the steering wheel and maximum lateral acceleration have been analysed. The distance to the obstacles where steering wheel angle is maximal has also been studied. Figure 13 and Figure 14 show the average maximum steering angle before obstacle A and obstacle B, respectively.

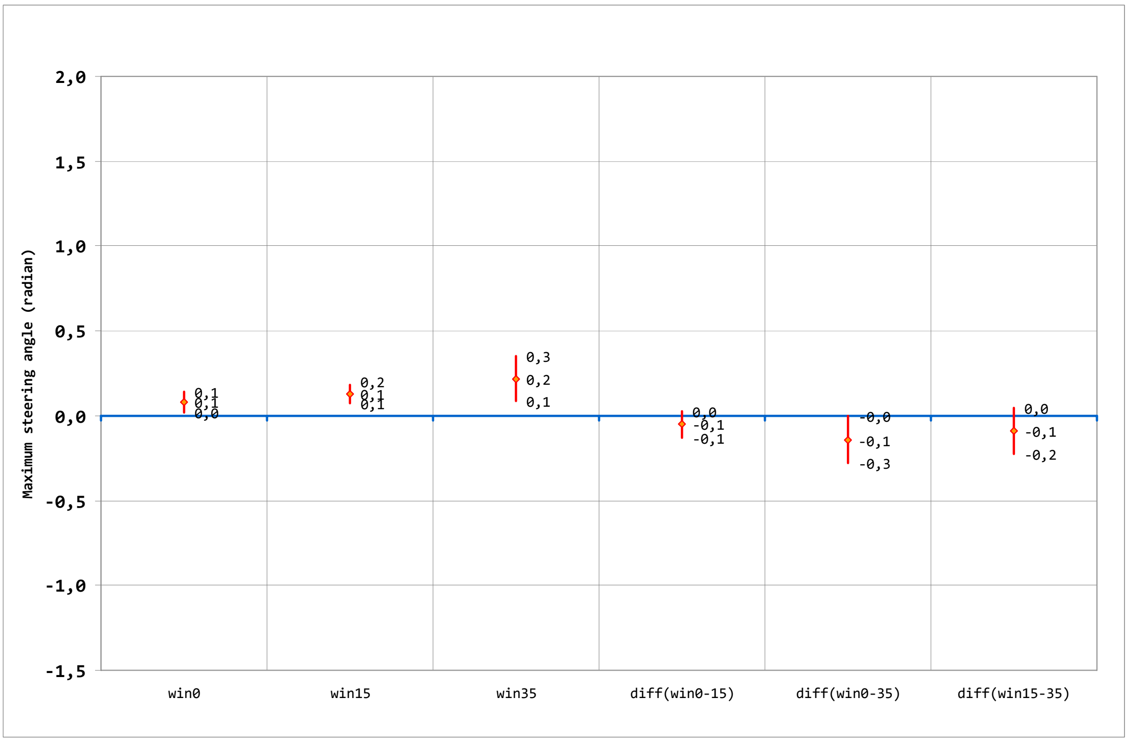


Figure 13 Maximum steering angle before obstacle A. Average value and differences between windscreens, including confidence interval for the different measurements.

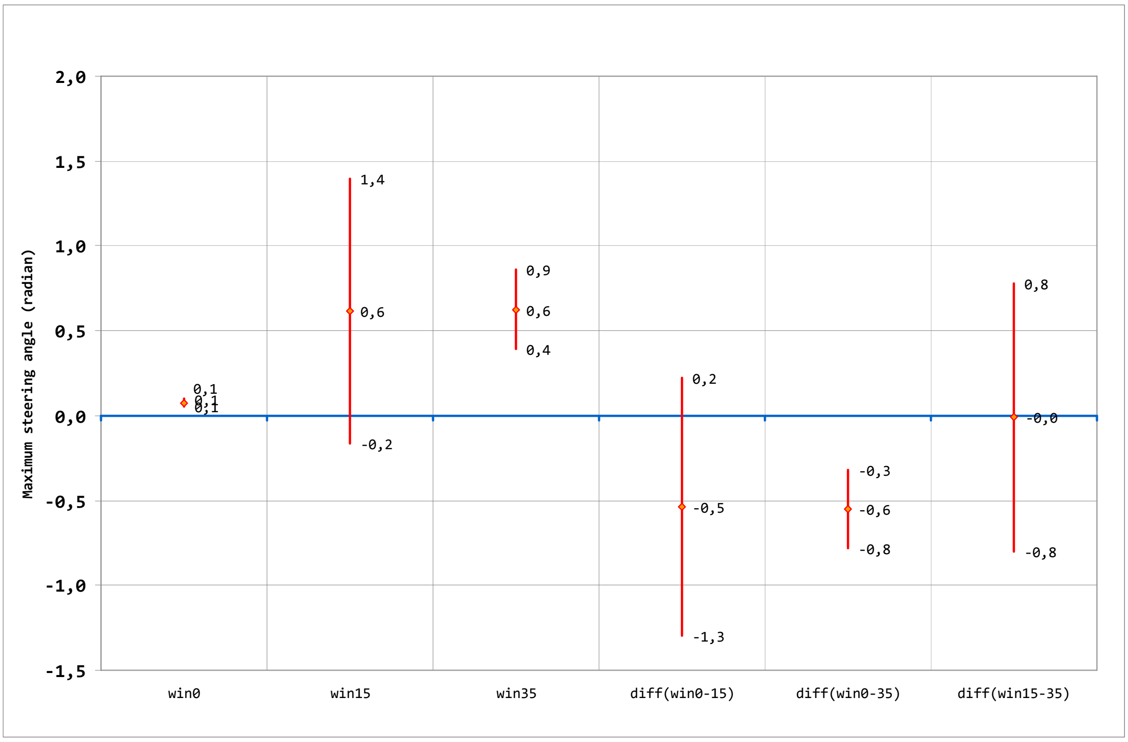


Figure 14 Maximum steering angle before obstacle B. Average value and differences between windscreens, including confidence interval for the different measurements.

The two figures indicate that the average maximum steering angle before the obstacles when driving with windscreen 0 was 0.08 radians for both obstacles. When driving with windscreen 15, the values were 0.13 radians before obstacle A and 0.62 radians before obstacle B, whereas the values for windscreen 35 were 0.22 and 0.63 radians, respectively. The differences in maximum steering wheel angle are statistically significant only between windscreen 0 and windscreen 35 and before obstacle B.

Figure 15 and Figure 16 show the average distance to obstacle A and obstacle B, respectively, where the steering angle was maximal.

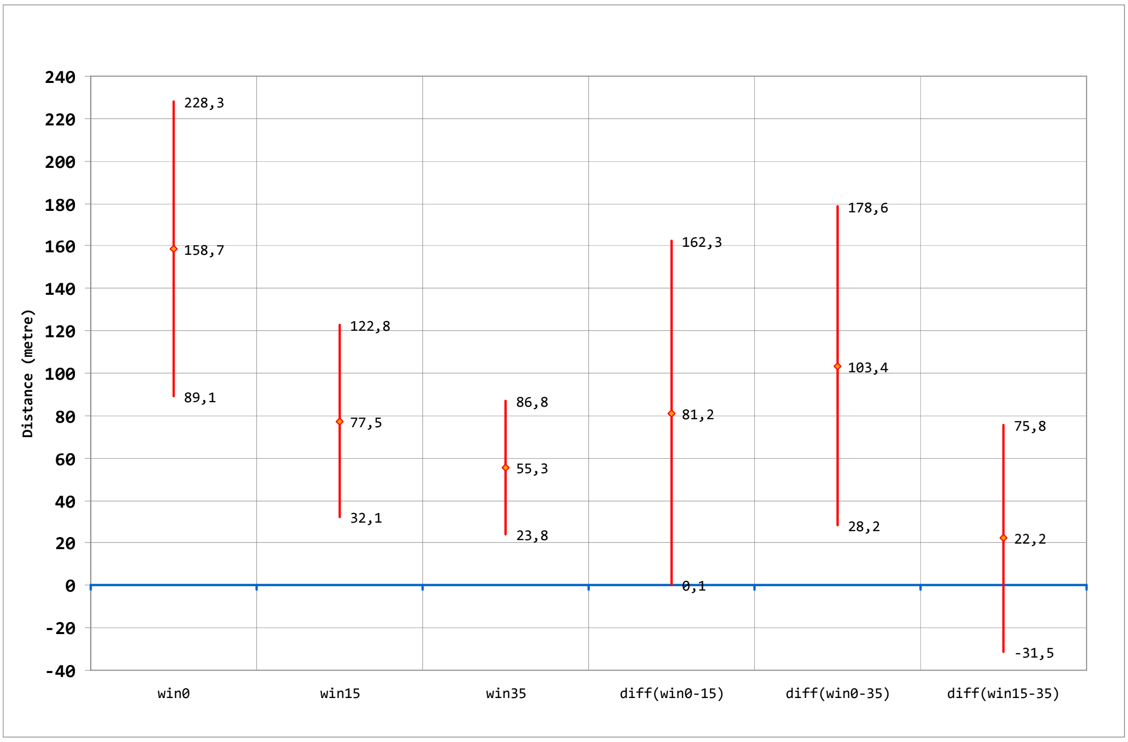


Figure 15 Distance to obstacle A with maximum steering angle. Average value and differences between windscreens, including confidence interval for the different measurements.

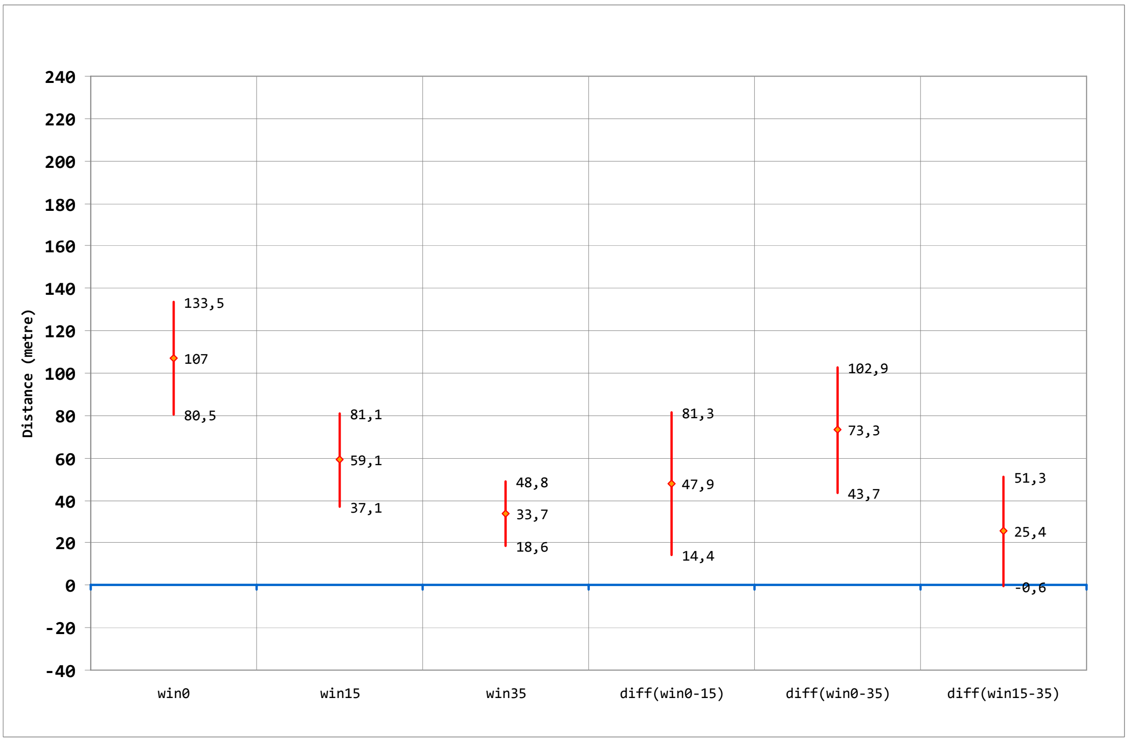


Figure 16 Distance to obstacle B with maximum steering angle. Average value and differences between windscreens, including confidence interval for the different measurements.

The two figures show that when driving with windscreen 0 the maximum steering wheel angle occurred at a distance of 159 and 107 metres, respectively, from the obstacle. When driving with windscreen 15, the distance to the obstacles was 78 and 59 metres, respectively and with windscreen 35, the distance was 55 and 34 metres, respectively. The difference in the distance between windscreen 0 and windscreen 15, when the maximum steering wheel angle was achieved, was 81 and 48 metres, respectively. The difference between windscreen 0 and windscreen 35 was 103 and 73 metres, respectively, whereas there was no significant difference between windscreen 15 and windscreen 35.

As a whole, the results show that the distance to the obstacles when maximum steering angle occurs, decreases with worn windscreens.

The average maximum lateral acceleration while avoiding the two obstacles is reported in Figure 17 and Figure 18.

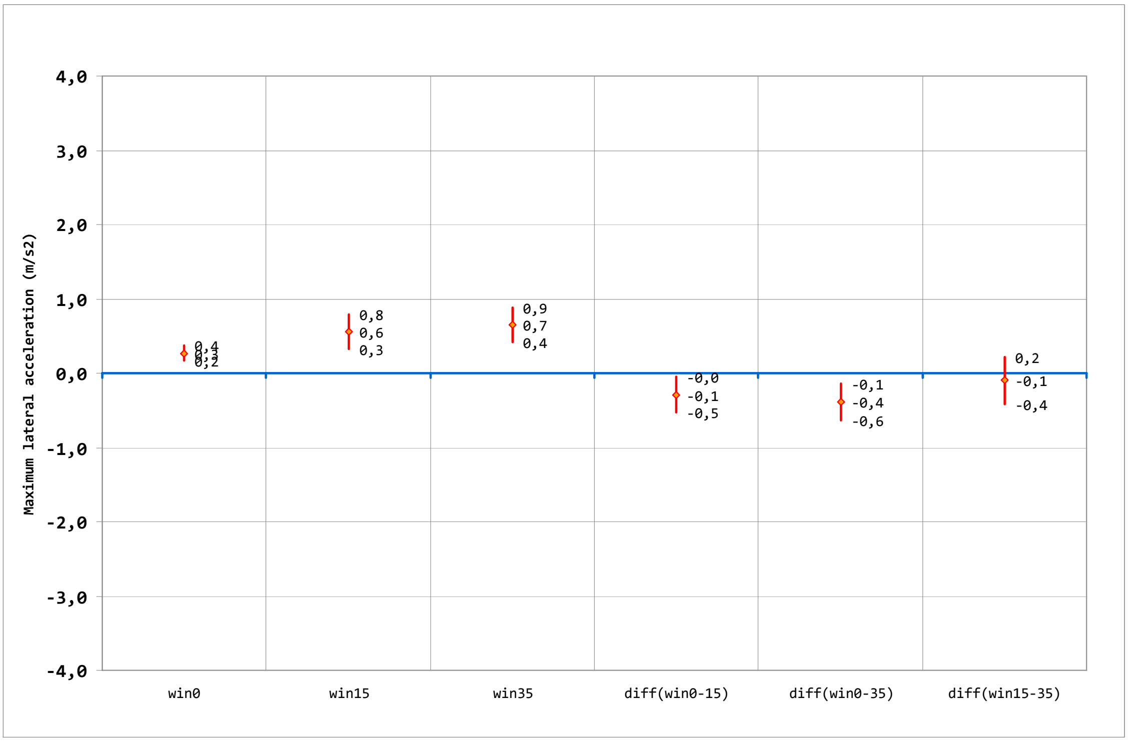


Figure 17 Maximum lateral acceleration while avoiding obstacle A. Average value and differences between windscreens, including confidence interval for the different measurements.

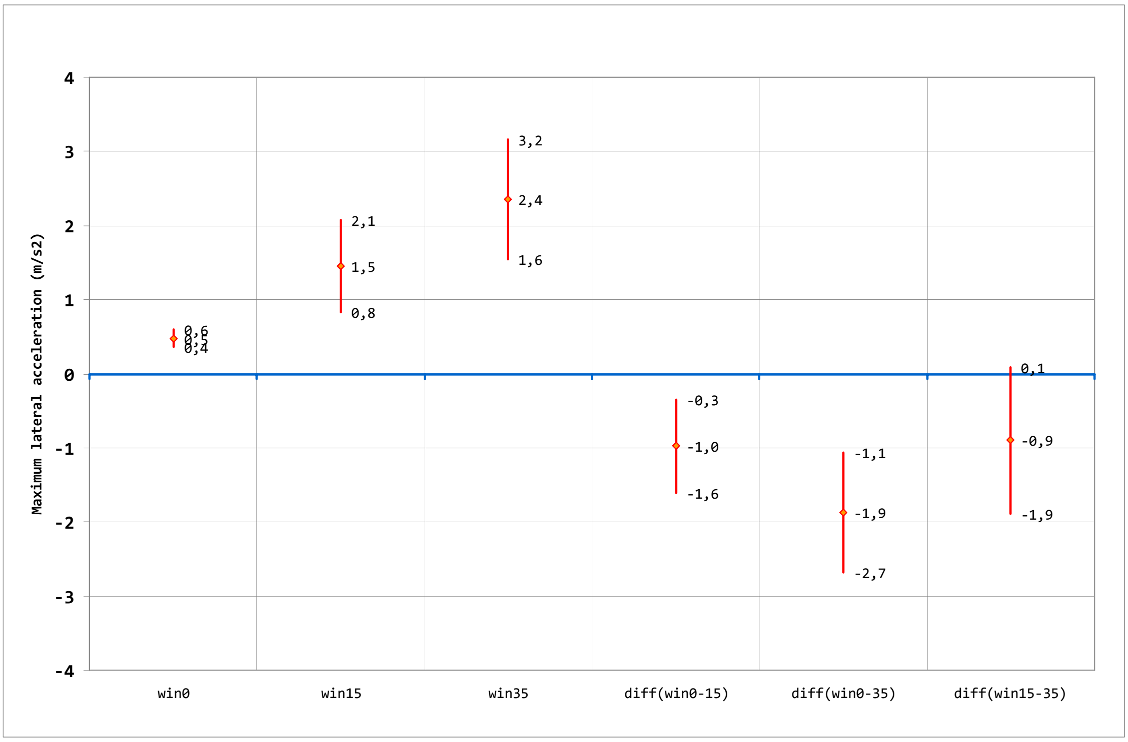


Figure 18 Maximum lateral acceleration while avoiding obstacle B. Average value and differences between windscreens, including confidence interval for the different measurements.

The two figures show that the drivers' average maximum lateral acceleration when passing obstacles with windscreen 0 was 0.27 and 0.48 m/s2, respectively, while driving with windscreen 15: 0.56 and 1.45 m/s2, respectively, and while driving with wind-screen 35: 0.66 and 2.35 m/s2, respectively. The difference between windscreen 0 and windscreen 15 was -0.29 and -0.93 m/s2, respectively, whereas the difference between windscreen 0 and windscreen 35 was -0.39 and -1.87 m/s2, respectively. The difference between windscreen 15 and windscreen 35 was not statistically significant.

The result shows that there is a significantly stronger lateral acceleration before obstacle B than before obstacle A with all windscreens. It also shows that there is stronger lateral acceleration when driving with the worn windscreens than when driving with the unused one.

The maximum steering angle is larger when driving with the worn windscreens than with the unused one and the maximum steering angle also occurs closer to the obstacle. This is seen most visibly in connection with obstacle B.

4.7 Passing obstacles

The variables analysed when the motor vehicle passes the obstacles are speed and lateral distance from the obstacle. These variables are measured when the front part of the simulated vehicle is on a level with the back part of the obstacle. The number of vehicles which collided with the obstacles has been registered, as well.

The speed when passing the obstacle is reported in Figure 19 and Figure 20.

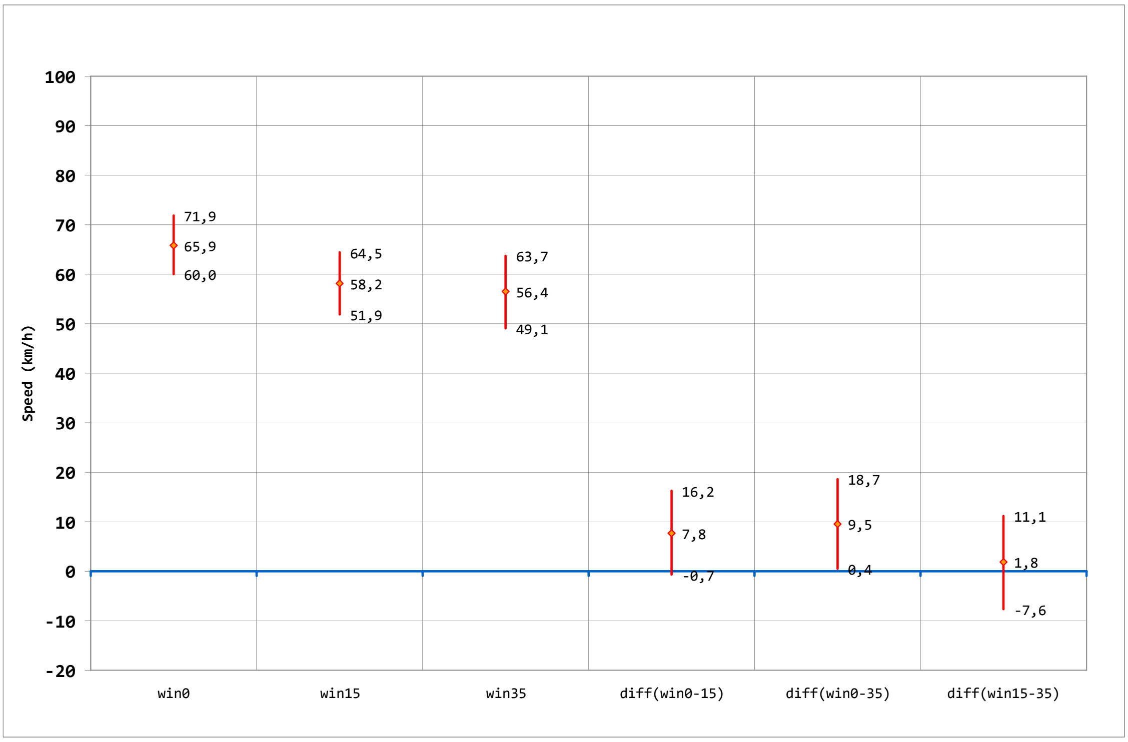


Figure 19 Speed at obstacle A. Average value and differences between windscreens, including confidence interval for the different measurements.

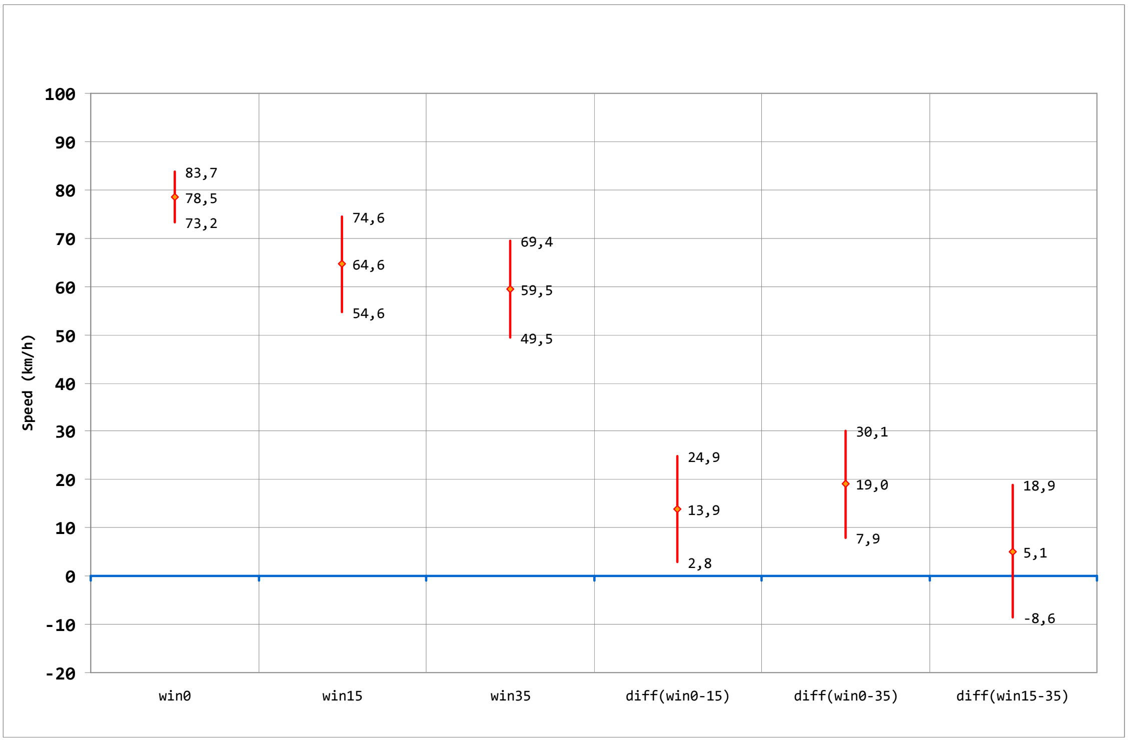


Figure 20 Speed at obstacle B. Average value and differences between windscreens, including confidence interval for the different measurements.

The two figures indicate that when the vehicles started to pass the obstacles, the average speed with windscreen 0 was 66 and 78 km/h, respectively, with windscreen 15 the speed was 58 and 65 km/h, respectively, and with windscreen 35 it was 56 and 59 km/h, respectively. The speed reduction between windscreen 0 and windscreen 15 was 8 (not sign.) and 14 km/h, respectively, whereas the reduction between windscreen 0 and windscreen 35 was 10 and 19 km/h, respectively. The reductions between windscreen 15 and windscreen 35 were not statistically significant.

The lateral position is calculated as the distance from the centre of the front of the car to the centre line of the road. This results in placement to the right of the centre line of the road, as seen from the driving direction, gives a negative values, whereas placement to the left of the centre line gives positive values for the lateral position variable. The average value of the lateral position is reported in Figure 21 and Figure 22.

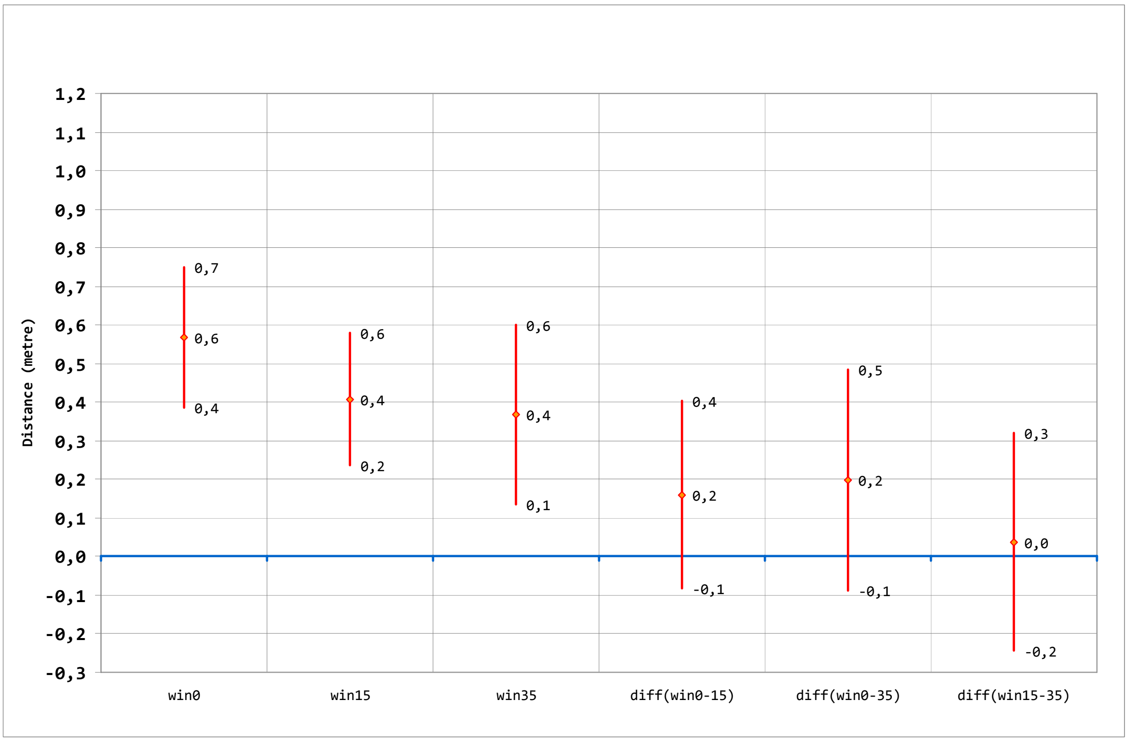


Figure 21 Distance from the centre of the vehicle to the centre line of the road at obstacle A. Average value and differences between windscreens, including confidence interval for the different measurements.

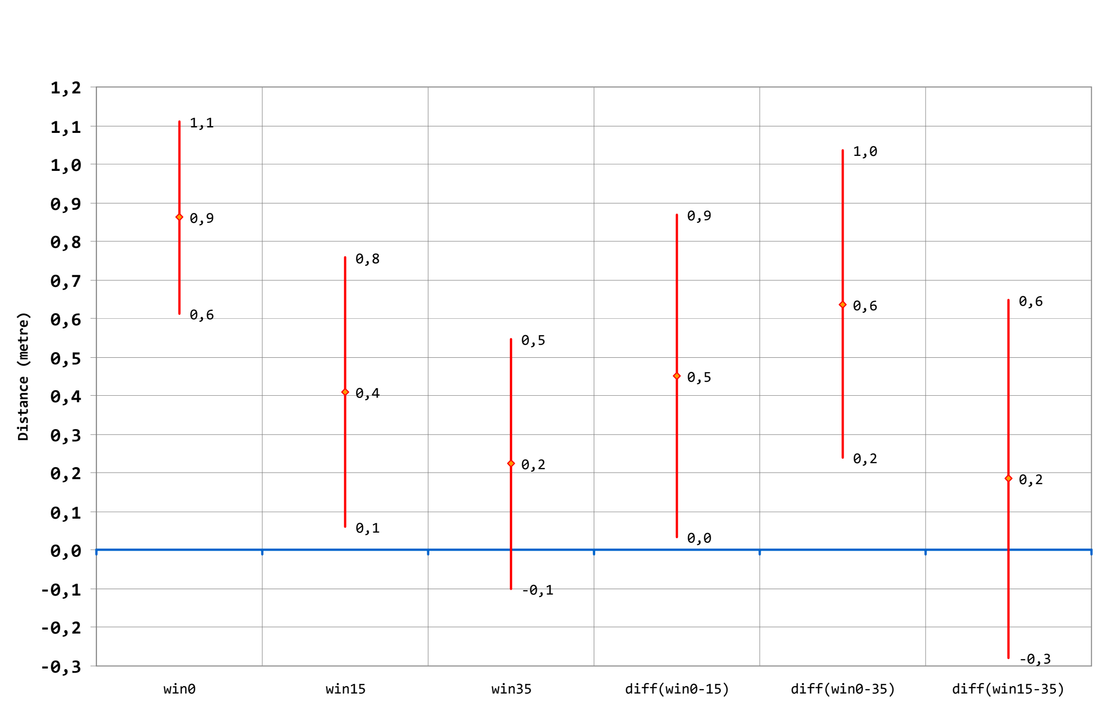


Figure 22 Distance from the centre of the vehicle to the centre line of the road at obstacle B. Average value and differences between windscreens, including confidence interval for the different measurements.

The figures show that the average distance to the centre line for driving with windscreen 0 was 0.57 and 0.86 metres, respectively, with windscreen 15: 0.41 metres for both obstacles and with windscreen 35: 0.37 and 0.22 metres, respectively. Obstacle A stood 2.1 metres from the centre line and obstacle B stood 1.5 metres from the centre line. The difference between the right front side of the simulated vehicle and the left back corner of the obstacles can, hence, be calculated. The distance between the vehicle and the obstacles when driving with windscreen 0, on average, was 1.9 and 1.6 metres, respectively, whereas the distance for windscreen 35 was 1.7 and 0.9 metres, respectively. These results show that drivers do not manage to avoid the obstacles to the same extent while driving with a worn windscreen.

Some drivers did not manage to avoid the obstacle and, therefore, collided. The drivers were not aware of any collision since no effects of collisions were simulated. In case of a collision the vehicle passed straight through the obstacle without any sound or vibrations. Collisions occurred twice when driving with windscreen 15 and four times with windscreen 35. All collisions, except one, occurred at the first obstacle of the first drive. For one driver, the collision, however, occurred at the second obstacle of the second drive. This driver had driven the first drive with windscreen 0. All collisions affected obstacle B.

4.8 Questionnaire results

In order to obtain the test subjects' subjective experience of driving with the different windscreens, they had to respond to a survey after each drive. The questions that had to be answered included:

1. How **worn do you experience this front windscreen to be?**

The test subject was supposed to make an estimate from 1 to 7.

Not worn	1	2	3	4	5	6	7	Very worn

2. How **safe** do you experience that it is to drive with this front windscreen?

The test subject was supposed to make an estimate from 1 to 7.

Very unsafe	1	2	3	4	5	6	7	Very safe

The results for the first question which concerned the wear of the windscreen are reported in Figure 23.

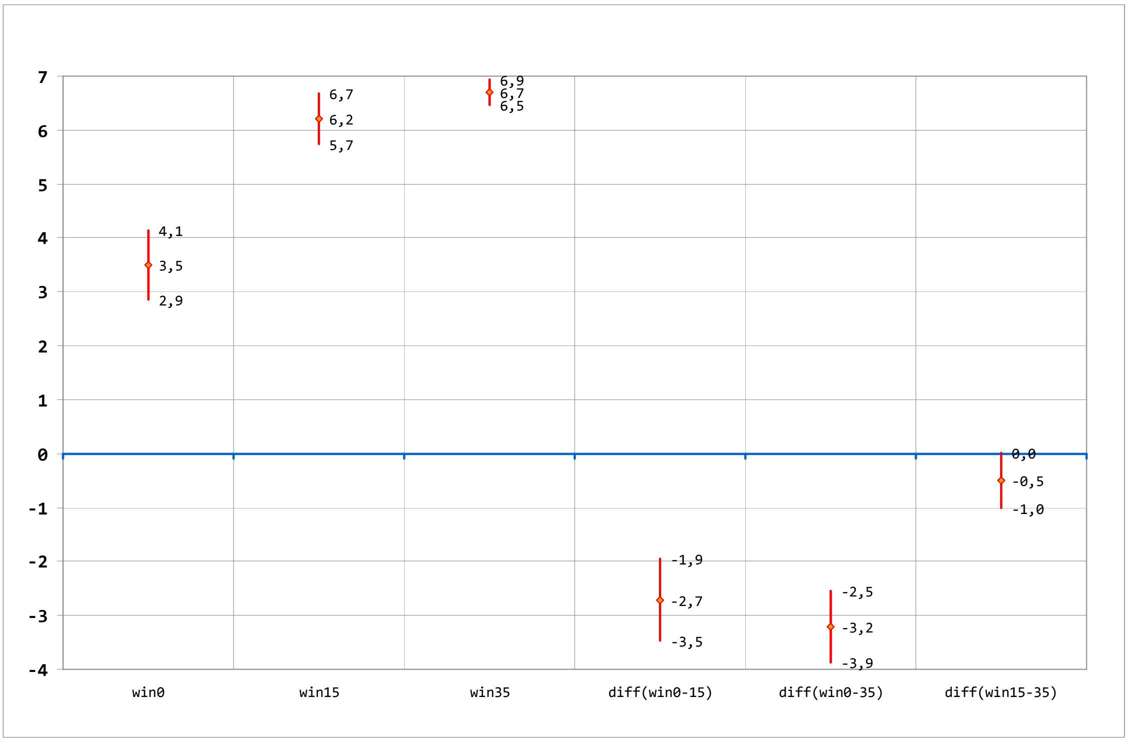


Figure 23 Drivers' grades of how worn the respective windscreen was experienced to be on the seven-grade scale where 1=not worn and 7=very worn. Average value and differences between windscreens, including confidence interval for the different measurements.

The figure shows that the drivers, on average, grade the degree of wear of the unused windscreen 0 with 3.5, a grade which is close to the middle of the interval on the scale of 1 to 7 where the value of 1 stands for “not worn” and the value of 7 for “very worn”. The average value for windscreen 15 was 6.2, and the average value for windscreen 35 was 6.7. The difference between windscreen 0 and the other windscreens shown in the figure was statistically significant, whereas there was no significant difference between windscreens 15 and 35.

The second question concerned how safe the test subjects graded driving with the different windscreens. The results for this question are reported in Figure 24.

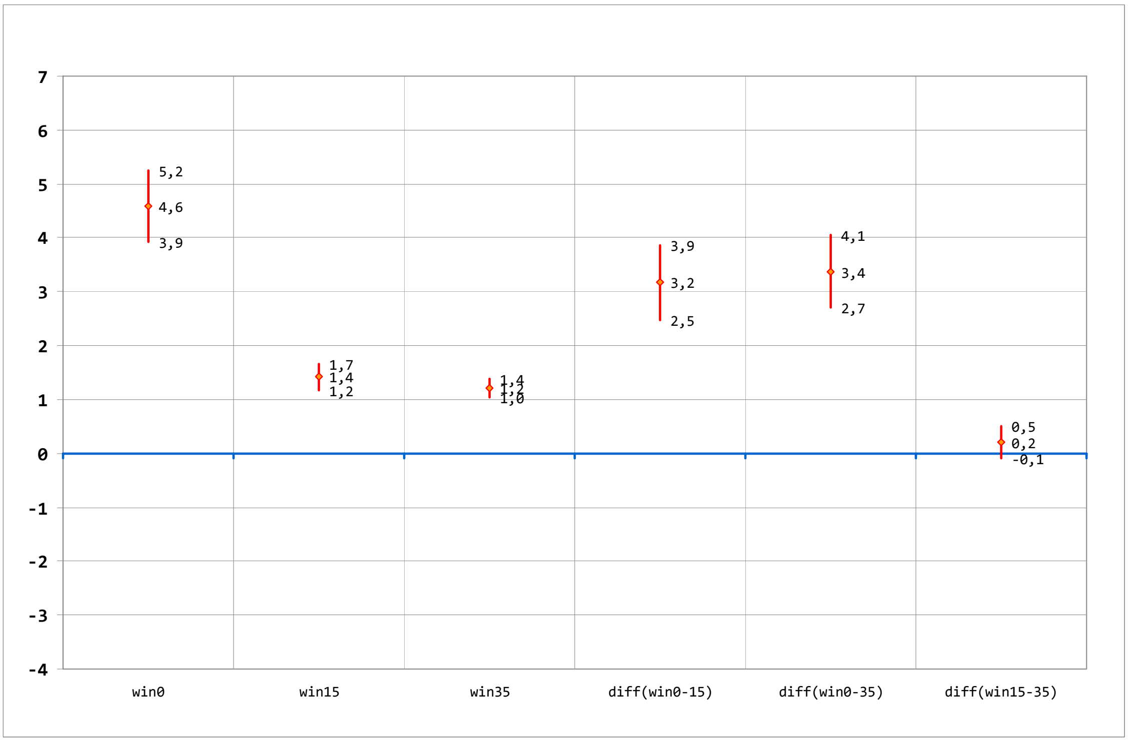


Figure 24 Drivers' grades of how safe the respective windscreen was experienced to be on the seven-grade scale where 1=very unsafe and 7=very safe. Average value and differences between windscreens, including confidence interval for the different measurements.

The figure shows that the safety of windscreen 0, on average, was graded 4.6 on a scale of 1 to 7 where 1 stands for "very unsafe" and 7 for "very safe". The response is close to the middle of the scale but on the safer side. Windscreen 15 is given an average value of 1.4 and windscreen 35 is given an average value of 1.2. Both these values are close to 1, which is "very unsafe". The unused windscreen is, thus, experienced to be significantly less worn and significantly safer than the two other windscreens.

After the last simulator drive, the test subjects had to grade how they experienced the simulator environment. The scale was from 1 to 7 where 1 is "very unrealistic" and 7 is "very realistic". The average grades of the drivers are presented in Table 3.

Table 3 Average values of the grades of the simulator experiences.

Questions	Average value
How realistic did you experience the road environment to be?	5.6
How realistic did you experience the direct light to be?	5.6
How realistic did you experience the steering function to be?	6.0
How realistic did you experience the braking function to be?	4.9
How realistic did you experience the driving task to be?	6.2
How realistic did you experience the simulated car's road manners to be?	5.8
Did you feel sick during the drive?	1.3 *

* The scale for the last question was from 1 to 7, as well, but 1 stood for "No, not at all" and 7 stood for "Yes, very".

The results presented in the table indicate that the test subjects experienced the environment and task in the simulator drive to be relatively realistic. What got the lowest grades was the car's braking function but this grade was still closer to realistic than to unrealistic. None of the test subjects started feeling sick and only a few felt minor discomfort during the simulator drive.

What was a complete new development for this test was the "direct light" in the form of a lamp directed at the windscreen. This was also experienced to be relatively realistic.

The average values and the dispersion in the answers are presented in Table 4.

Table 4 Experienced level of realism in the experiments. Average values and dispersion measurements for grades on a 7-grade scale, as well as potential sickness (1= no, not at all; 7= yes, very).

	Road en-viron-ment	Direct light	Steering function	Braking function	Driving task	Road manners	Did you feel sick?
Average value	5.6	5.6	6.0	4.9	6.2	5.8	1.3
Standard deviation	1.10	1.28	0.93	1.33	0.78	0.93	0.53
Variance	1.20	1.64	0.87	1.77	0.61	0.87	0.28
Minimum	3	3	4	2	5	3	1
Maximum	7	7	7	7	7	7	3
Number	24	24	24	24	24	24	24
Conf. interval (95%)	±0.5	±0.5	±0.4	±0.6	±0.3	±0.4	±0.2
1 = Very unrealistic							79.2
2				4.2%			16.7
3	8,3%	4.2%		12.5%		4.2	4.2
4		16.7%	4.2%	20.8%			
5	33.3%	29.2%	29.2%	25.0%	20.8	29.2	
6	37.5%	12.5%	29.2%	29.2%	37.5	45.8	
7 = Very realistic	20.8%	37.5%	37.5%	8.3%	41.7	20.8	

The table indicates that the dispersion in the answers is relatively small.

The survey included questions about how the subjects described themselves as drivers. There was nothing in the results from those answers that justified any further analysis.

5 Discussion

As there is no direct single measurement of traffic safety, we have measured a number of variables under different conditions in this study in order to determine what effect worn windscreens exert on traffic safety. The subject has been to determine if driver behaviour has deteriorated due to the worn windscreens.

At first, the average speed over a stretch was measured in order to give a common basic level for what speed the driver chooses with the different windscreens. This gave information that the drivers reduced their speed by approximately 15 km/h when they were driving with the worn windscreens compared to when driving with an unused windscreen. When we subsequently examined what happened when the drivers were forced to avoid obstacles on the road, we observed that the drivers were not as successful with the evasive manoeuvre when the windscreen was worn, despite the reduction in the speed. The drivers discovered the obstacle later, braked more strongly and undertook a more vigorous evasive manoeuvre. This indicates a more hazardous driver behaviour and in other words lower traffic safety.

When the lateral distance between the simulated vehicle and obstacle B was measured, it was observed that the average distance to the obstacle when driving with the unused windscreen was 1.6 metres but only 0.9 metres when driving with the most worn windscreen. This indicates that the drivers have not managed to swerve away from the obstacle as much with the most worn windscreen as with the unused one, despite the fact that the drivers had maintained a lower speed and made a more vigorous evasive manoeuvre.

Some drivers did not manage to avoid the obstacle. Two collisions occurred while driving with windscreen 15 (out of 48 obstacle passes with windscreen 15) and four collisions occurred while driving with windscreen 35 (out of 48 obstacle passes with windscreen 35). However, none of the 48 obstacle passes while driving with the unused windscreen, led to a collision. The share of collisions was 4% with windscreen 15 and 8% with windscreen 35. Considering that these incidents could have been accidents in real traffic, the results indicate that driving with worn windscreens under such difficult conditions as in direct light entails a great risk of accidents. Because of the low number of observations, it was not considered meaningful to statistically test these results. Nevertheless, they indicate that driver behaviour and safety margins are influenced negatively by the worn windscreens.

In general, it is difficult to determine if it is possible to transfer the results from simulator studies to real traffic. One advantage of this method is, however, that the effect of different parameters can be refined and differentiated as all surrounding factors can be kept the same for each test subject, unlike experiments in real traffic. It would, however, be desirable to validate the method using data from drives in real traffic.

One problem in this study can be that the experimental situation is experienced to be unrealistic and thereby affect driver behaviour. Certain questions in the survey were, therefore, intended to reflect the test subjects' subjective opinion of how they experienced the experiment. The results indicate that the test subjects experienced the environment and task to be relatively realistic. Nevertheless, it should be kept in mind that this is a study of driver behaviour in a simulator. The measured driver behaviour is, therefore, not directly transferrable to real environment and traffic. It might be possible that the test subjects drive more hazardously in the simulator than in real traffic. This is also an experimental situation where the test subjects know that they are studied in detail. This can affect the drivers and make them try to present a good driving result, which probably does not fully correspond to the way they normally drive.

The drivers were also given the task to grade how worn they experienced the windscreens to be and how safe they thought it was to drive with the respective windscreen. The replies indicated that the unused windscreen was experienced to be significantly less worn and significantly safer than the two other windscreens.

A worn windscreen is only one of the factors that influence visibility. Another factor is dirt, which presumably interacts with the worn windscreens as it can be harder to remove dirt if the windscreen is worn. An additional factor is the quality and ability of the windscreen wipers to remove dirt from the windscreen. All windscreens in this study were thoroughly cleaned in order to measure only the effect of the wear on the windscreen and nothing else. The effect of worn windscreens in combination with dirt in different degrees has not been investigated in this study.

We obtained considerable variations between test subject in this study. For example, the sight length for windscreen 0 varied from 82 to 323 metres. There can be several reasons for this. There is dispersion in the test subjects' age and driving experience. One explanation can, therefore, be age differences among the test subjects. On the one hand, greater age may lead to greater experience and better scanning ability, which leads to earlier discovery of obstacles. On the other hand, greater age may lead to poorer eyesight and longer reaction time. Only test subjects who needed neither glasses nor lenses for car driving were recruited. The test subjects' visual acuity, however, was not tested. Because of the considerable variation from one test subject to another, a within-group design, which handles this problem, was selected.

Experiences from previous studies have shown that drivers discover objects later when they drive in a simulator rather than when they drive in real traffic. The reason for this is that the contrast in the simulator is not as high as in real traffic environment. The level of the absolute values might, therefore, be uncertain. This is why the relative difference between different windscreens gives a better measurement than the absolute values.

In this experiment dazzling of the sun was studied, but the problems with worn windscreens also arise in other situations, for example, in night traffic, in connection with the dazzling due to oncoming traffic. The problems in night traffic have been studied previously at VTI and the results from those field studies also show that the detection distance diminishes with worn windscreens (Lundkvist & Helmers, 1988). Even if the present study was performed in a simulator environment, which has its limitations, it can be ascertained that driving in direct light with a worn windscreen has negative effects on driver behaviour. In real traffic, there are many more factors that can influence visibility and dazzling, such as dirt and moisture. Therefore, there is a risk that the effect on driver behaviour when driving in real traffic can be significantly greater than what has been measured in this study. The study has demonstrated negative effects on driver behaviour already with a windscreen which has been used for 150,000 km. Since there is probably a considerable number of vehicles in traffic with windscreens which have been used 150,000 km or more, the problem should be taken seriously.

As the results from the three tested windscreens do not seem to follow a linear function, it would be desirable to conduct corresponding tests also with windscreens driven, for example, 50,000 and 100,000 kilometres, respectively. It could also be of interest in connection with a future study to analyse the significance of the age of the driver.

References

Lundkvist, Sven-Olof and Helmers, Gabriel (1988). **Detection distances to obstacles on the road seen through windscreens in different states of wear.** Statens väg- och trafikinstitut. VTI rapport 339A. Linköping.

Lundkvist, Sven-Olof och Helmers, Gabriel (1993). **Siktsträcka till hinder vid nedsatt syn och/eller sliten vindruta.** Statens väg- och trafikinstitut. VTI rapport 382. Linköping.

VTI (2009-02-19). **Körsimulatorer.** Internet 09:35 2009-07-01 http://www.vti.se/templates/Page____2584.aspx

Vägverket (2009-03-22). **Körsäkerhet.** Internet 09:25 2009-07-01. http://www.vv.se/Startsida-foretag/Trafiken/Fordon-och-trafikant/Bil/Sakerhet-i-bil/Sakerhetsegenskaper/Korsakerhet/

Participant Instruction

Participant Instruction

Your task is to drive a car in a simulator. The experiment continues for approximately 2 hours and its purpose is to test different front windscreens while driving in direct light.

The experiment is divided into three parts, one simulator drive for each front windscreen. Each drive takes approximately 10 minutes and you leave the simulator for approximately 30 minutes between drives. Before you start the first drive, you have to train driving the simulator.

Training

During the training period, you have to get used to driving the simulator. The training takes approximately 10 minutes. You may ask the test leader questions during the whole training. The training is carried out on the same type of road as the experiment itself. After the training, the test leader summarises your task again before the experiment starts.

Experiment

You will drive a simulator drive with each front windscreen.

During each drive, you will first drive ordinary country driving where we want you to drive as you usually do under corresponding conditions in real traffic. Then, you will conduct a measurement of sight length where you drive along a straight road at 40 km/h and press a response meter button when you see a cone placed on the right side of the road. The text “Stop – Brake” will come up after each drive. Then, the simulator will park and the test leader will help you out.

You will have to answer a couple of questions before the next part of the experiment.

You will answer additional questions after the experiment.

General Information

The car you drive has an automatic transmission.

The speed limit on the road where you are supposed to drive is 90 km/h and your task is to drive as you would normally do.

The test leader can see and hear you in the simulator during the whole experiment. The test leader will not talk to you when you run the experiment but it is important that you let the test leader know as soon as something does not feel good. You may abort the experiment at any point; you can do this by letting the test leader know that you wish to terminate the experiment. You should not open the door to the simulator yourself.

Summary

- Drive as you are used to driving under corresponding conditions in real traffic.
- Notify the test leader if something does not feel good.

27.05.2009

Worn Windscreens

Informed Consent

I, the undersigned, have become familiar with the written and oral information concerning the *Worn Windscreens* study and accept to take part under the conditions that were stated. I also accept video recordings of my face from the tests to be used during presentations of the study. I know that I have the right to terminate the study without providing an explanation.

Date:

Signature:

Printed name:

Anne Bolling

Project manager

Artificial Sun

Measurement of luminance in simulator SIM III without artificial sun.

Place	Illuminance [lx]	Notes
Scenario – light green objects	18	grass
Scenario – dark green objects	10	dark trees
Scenario – road	16–23	depending on road surface
Scenario – blue sky	60	good weather, daylight
Scenario – white (clouds)	90	good weather, daylight
head rest	2	where driver has head, only projector light

Lamp

Halospot 50W 24º, halogen

Distance: Lamp – driver 2.8 m

Lamp – middle of field of vision 0.65 m

The angle between the horizon and the lamp was approximately 13 degrees

Luminous intensity on the windscreen with the lamp on, 260 lux

Luminous intensity, driver head with lamp on and glare shield 4.4 lux

Survey Questions

Background Questions   Fp no. ……

1. Which year were you born? ___________________

2. Which year did you obtain your driver's licence? ________________

3. How many kilometres do you drive per year? ___________________

4. In which traffic environment do you drive most often? ____________

Country driving _____________

City driving ______________

How would you describe yourself as a driver and how do you drive?

Grade each aspect below on a scale of 1 to 7.

	1	2	3	4	5	6	7	
Bad								Good
Slow								Fast
Uneasy								Calm
Careful								Risk-taking
Hesitant								Determind
Concentrated								Easily distracted
Nervous								Secure
Defensive								Offensive
Attentive								Inattentive
Good planning								Impulsive
Fun								Boring
As often as you can								Only when necessary

Questions after each drive Fp no. ………

1. How **worn do you experience this front windscreen to be?**

The test subject is supposed to make an estimate from 1 to 7.

Not worn	1	2	3	4	5	6	7	Very worn

2. How **safe** do you experience that it is to drive with this front windscreen?

The test subject is supposed to make an estimate from 1 to 7.

Very unsafe	1	2	3	4	5	6	7	Very safe

Follow-up questions after last drive Fp no. ………

1. How realistic did you experience the road environment to be?

Very un-realistic	1	2	3	4	5	6	7	Very realistic

2. How realistic did you experience the direct light to be?

Very un-realistic	1	2	3	4	5	6	7	Very realistic

5. How realistic did you experience the steering function to be?

Very un-realistic	1	2	3	4	5	6	7	Very realistic

6. How realistic did you experience the braking function to be?

Very un-realistic	1	2	3	4	5	6	7	Very realistic

7. How realistic did you experience the driving task to be?

Very un-realistic	1	2	3	4	5	6	7	Very realistic

8. How realistic did you experience the simulated car's road manners to be?

Very un-realistic	1	2	3	4	5	6	7	Very realistic

9. Did you feel sick during the drive?

No, not at all	1	2	3	4	5	6	7	Yes, very

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VTI är ett oberoende och internationellt framstående forskningsinstitut som arbetar med forskning och utveckling inom transportsektorn. Vi arbetar med samtliga trafikslag och kärnkompetensen finns inom områdena säkerhet, ekonomi, miljö, trafik- och transportanalys, beteende och samspel mellan människa-fordon-transportsystem samt inom vägkonstruktion, drift och underhåll. VTI är världsledande inom ett flertal områden, till exempel simulatorteknik. VTI har tjänster som sträcker sig från förstudier, oberoende kvalificerade utredningar och expertutlåtanden till projektledning samt forskning och utveckling. Vår tekniska utrustning består bland annat av körsimulatorer för väg- och järnvägstrafik, väglaboratorium, däckprovningsanläggning, krockbanor och mycket mer. Vi kan även erbjuda ett brett utbud av kurser och seminarier inom transportområdet.

VTI is an independent, internationally outstanding research institute which is engaged on research and development in the transport sector. Our work covers all modes, and our core competence is in the fields of safety, economy, environment, traffic and transport analysis, behaviour and the man-vehicle-transport system interaction, and in road design, operation and maintenance. VTI is a world leader in several areas, for instance in simulator technology. VTI provides services ranging from preliminary studies, highlevel independent investigations and expert statements to project management, research and development. Our technical equipment includes driving simulators for road and rail traffic, a road laboratory, a tyre testing facility, crash tracks and a lot more. We can also offer a broad selection of courses and seminars in the field of transport.

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