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Dick De Waard , Thigri Van den Bold, & Ben Lewis-Evans

Abstract

It has been suggested that a driver's hand position on the steering wheel can reflect the perceived risk of the road context **(**Walton, D. & Thomas, J.A. (2005), Naturalistic observations of driver hand positions. *Transportation Research Part F*, *8*, 229-238, Thomas, J.A. & Walton, D. (2007), Measuring perceived risk: self-reported and actual hand positions of SUV and car drivers. *Transportation Research Part F, 10,* 201-207). These original studies were based on field observations where only a part of the steering wheel could be viewed. In the present study hand positions were observed in a driving simulator during the performance of a demanding task; merging into motorway traffic. In the current study the whole steering wheel could be observed and hand positions were classified in three categories: high control, medium control, and low control. Differences in hand position between different traffic conditions were limited, and hand position did not correlate with self-reported risk or self-reported mental effort, but changes in hand positions do seem to coincide with changes in workload demand. It is therefore concluded that hand position can give some information about mental workload.

1. Introduction

In an on-site observation study Walton and Thomas (2005) found that driver hand position on the steering wheel was related to driving on multilane roads at higher speeds. In that, during these conditions a higher proportion of drivers were observed to place both of their hands on the top of the wheel. The same authors also reported that Sports Utility Vehicle (SUV) drivers more frequently hold the steering wheel with only one hand than other car drivers and generally viewed their vehicles as significantly safer (Thomas & Walton, 2007). Based on these findings Walton and Thomas have suggested that hand position can be used as a way to measure driver's perception of risk.

However there are some potential problems with this conclusion. Firstly, at no point during either study was perceived risk directly measured. Even in the 2007 study, which included a questionnaire, no direct measure of risk was obtained from participants. Rather that lower or higher risk is being perceived by drivers is inferred by the authors, and here there are some inconstancies. For instance while there was a significant effect of speed and being on a six lane motorway on hand position, there was no effect of driving on objectively more risky roads (accident black spots) which were clearly signposted as high risk areas (Walton & Thomas, 2005). It should also be noted that six lane, divided motorways are actually very safe roads in terms of the risk of being involved in a crash (e.g. Gray, Quddus, & Evans, 2008). Secondly, increasing levels of traffic density were found to be related to less hands being on top of the steering wheel, rather than the expected more hands on the wheel, although as the authors point out this is likely to be confounded by the lower speeds at these sites (Walton & Thomas, 2005). It also does not necessarily follow that because SUV drivers indicate in a questionnaire that they believe their vehicle is safer means that during moment to moment driving they perceive any more or less risk than other road users when actually driving on the road. It may only be that when asked to take time and think about these matters while filling in a questionnaire that risk comes into their mind, and they indicate that their vehicles are safer.

Thirdly, whether drivers can continuously monitor feelings or perceptions of risk, as suggested by some theories of driver behaviour (Fuller, 2008; Wilde, 1976), is still a matter of debate. Other theories of driver behaviour, such as zero-risk theory (Näätänen & Summala, 1976), and the multiple monitor model (Summala, 2005) claim otherwise suggesting that risk is only experienced once a certain threshold has been crossed. Recent evidence in terms of ratings of feeling of risk supports this threshold relationship (Lewis-Evans & Rothengatter, 2009). However even if a threshold model is adopted, the hands on measure may be of use as a measure to see when this threshold is crossed.

It could also be argued that hand positions reflect a response to the demand of the situation. Hand positions therefore could be more closely related to mental workload and the need to control steering rather than a response to perceived risk. However, ratings of feelings of risk, task difficulty and mental workload, at least in experimental conditions, have been found to be strongly correlated with each other (Fuller et al., 2008; Lewis-Evans & Rothengatter, 2009).

If hand positions reflect how drivers perceive the traffic situation, then the observation of hand positions could also be used as research instrument in experimental situations. Behaviour such as hand position can be easily observed during driving in experimental situations, and does not require participants to give subjective responses to questionnaires, or the use of expensive equipment. This could be useful, as knowing how drivers perceive the risk or demand of a situation could help explain their driving behaviour, e.g. their speed choice (e.g., Goldenberg & Van Schagen, 2007, Kaptein & Claessens, 1998).

In principle there are many combinations of hand positions possible, although when driving on a straight road the left hand is most likely on the left hand side of the wheel, and the right hand on the right hand side. Hand positions on the steering wheel are objectively related to vehicle control; e.g., one hand is likely to give less control than two. One hand on the left hand side of the wheel, and one on the right hand side gives most control over the vehicle in emergency situations (see also Walton & Thomas, 2005). These hand positions could be called the safest, or "high control" positions. However, due to a restricted view on the interior of passing cars in the previous studies, Walton & Thomas (2005) and Thomas & Walton (2007) had to limit themselves to scoring of hand positions in the top half of the steering wheel. They scored positions as 0, 1, or 2; the number of hands visible in the top half of the steering wheel. One hand on 9 o'clock and one on 3 o'clock was scored as 2, as was two hands on (nearly) 12 o'clock, and one hand on 12 o'clock and one on 9 o'clock, although the latter two positions do not give as much control as the 9 with 3 o'clock, or 10 with 2 o'clock positions. The 9 and 3 o'clock and 10 and 2 o'clock positions in particular are trained in driving schools, to give high control of steering. With airbags becoming a standard part of the steering wheel, 9-3 o'clock position is especially promoted nowadays, due to the risk of arm or wrist injury in case of airbag inflation.

In the previous studies Walton & Tomas (2005) and Thomas & Walton (2007) observed drivers in real traffic. Obviously the advantage of this is that drivers can be expected to behave naturally. However, many studies nowadays are performed in driving simulators, and on the basis of these studies predictions of behaviour in real traffic are made. Driving simulators are widely accepted as research tool and have as major advantage that they provide high control over environmental conditions and presented stimuli (Matthews et al., 1998, Reed & Green, 1999, Fisher et al., 2009). Therefore it would be useful to know how hand position in a controlled environment such as a driving simulator reflect mental workload or experienced risk. It would also be useful to know if hand position is comparable to what is observed in the real world. Using a simulator also allows for hand position to be observed on the whole steering wheel and not just the top half as was the case in the naturalistic observations by Walton & Thomas (2005).

In the present experimental study we observed hand position during the mentally demanding manoeuvre of merging into heavy motorway traffic where, in total, participants completed a merge manoeuvre seven times. During each manoeuvre hand position was observed at three moments; after having started the engine and driving away, just before changing lane to the main road, and whilst driving in the fast lane of the motorway. So 21 repeated observations per participant were collected. The observation of hand position, as reported here, was part of a larger study that focussed on effects of increased levels of Heavy Goods Vehicles (HGVs), the effects of acceleration lanes of different length, and the effects of a slowly driving lead car. The results of this study can be found in De Waard, Dijksterhuis, & Brookhuis (2009). Ratings of invested mental effort as well as risk ratings were obtained in order to gain a direct measure of these variables and their relationship to hand position.

Also in the study the performance of a group of older drivers was compared with younger drivers. With increasing age visual functions and cognitive performance, such as divided attention, decline (e.g. Wood, 2002). Older drivers usually compensate very effectively for any declines however, for example by slowing down to create more time to react and manoeuvre as can be seen in conditions when they have to turn left in a right hand driving countries (Brouwer & Ponds, 1994, Brundell-Freij & Ericsson, 2005). This strategy, of creating more time by slowing down, would not be effective when merging into traffic however, as this actually worsens the situation. It would increase the speed difference between the driver's speed and the speed of traffic on the main road meaning that more space to successfully complete the merging manoeuvre would be required.

The following hypotheses can be formulated:

H1. Between different moments in a ride and between different conditions hand position is expected to reflect effects of task demands on mental workload; a higher control position is expected in higher mental workload situations.

H2. Between different moments in a ride and between different conditions hand position is expected to reflect perceived risk; a higher control position is expected in higher risk situations.

H3. A larger speed difference with traffic on the main road will occur for older drivers leading to higher mental effort and higher risk, which will be reflected in hand position.

Conditions include different types and intensities of traffic on the main road, the length of the acceleration lane, and the presence of a lead car that restricts speed choice.

2. Method

2.1 Simulator

The driving simulator consists of a vehicle mock-up with a functional steering wheel, indicators, and pedals. The simulator car was equipped with an automatic gear for this experiment. The simulator is surrounded by three frontal 32-inch diagonal LCD screens, and one additional screen on the left-hand side behind the participant, to enable a "look over the left shoulder" when merging. Each screen provides a 70° view, leading to a total 280° view of the driving environment. The simulator uses software developed by ST Software©, and is capable of simulating fully interactive traffic.

For the experiment a section of a Dutch motorway was created, consisting of two 3.6 metre wide lanes and a hard shoulder of 3 metres. One acceleration lane and three exits provided entrance to and exit from the motorway.

2.2 Participants

All participating drivers had held a full licence for a minimum of five years (mean for younger drivers 10 years; mean for older drivers 47 years) and drove more than 5000 kilometres per year (mean annual distances driven were 14 000 km for the younger drivers and 10 000 km for the older drivers). Seventeen younger (13 men, 4 women, mean age 29.5 years, SD 4.7, range 24-39) and 16 older drivers (14 men, 2 women, mean age 70.3 years, SD 4.9, range 64-81) completed the experiment.

2.3 Driving environment

The standard length of the acceleration lane was 300 metres, but the effects of an extended acceleration lane and a short acceleration lane were also evaluated. Short acceleration lanes, 150 metres in length, can be found at many different locations in the Netherlands. Merging from these shorter lanes is expected to be more mentally demanding, as the speed difference between the merging car and traffic on the main road is expected to be larger. An extended lane of 450 m in length was also included in the study. On extended lanes drivers can more easily reach the target speed, that being the speed of traffic on the main road, which should make merging less demanding. In two conditions a slowly driving lead car was also present during the initial acceleration phase, which did not drive faster than 80 km/h. In those two conditions there was also a car driving behind the simulator car, to increase time pressure (see Table 1). Traffic on the motorway was manipulated into three levels:

1. <u>Passenger cars</u>: Only private cars, a relatively high traffic volume of a total of 3600 vehicles/hour (1800 per lane), travelling at an average speed 110 km/h (SD 9 km/h), with an average time-headway of 2 seconds in the right hand (merge) lane, and 3 seconds in the left hand (fast) lane.
2. <u>Mix</u>: A mix of HGVs and private cars which was representative of current traffic conditions in the Netherlands. With about 200-250 HGVs /hour all in the right hand (slow) lane and about 1500 private cars / hour. The average time-headway was 2

seconds. Target speeds were 80 km/h for HGVs, and 120 km/h for passenger cars. The passenger cars adapted their speed to HGVs if they could not overtake.

3. HGV Column: A column of HGVs, on average 950 HGVs/hour, all in the slow lane. The average speed was 80 km/h, SD 4 km/h, and the average time-headway was 2 seconds. In addition to HGVs there were also private cars (about 1500 / hour), mainly in the left hand lane.

The task of merging into traffic is described in more detail in De Waard et al. (2008, 2009).

2.4 Scoring of hand position

Hand positions were scored using a different method than that used in the previous study by Walton & Thomas (2005). Instead being restricted to the top half of the steering wheel, the whole steering wheel was able to be observed and could be scored in more detail. The position of both hands was initially marked on a drawing of a steering wheel, but was later recoded into three categories:

1. High control

High control meant that the hands were in the optimal position for vehicle control. The right hand should be on the steering wheel in the area of 2 or 3 o'clock, the left hand in the area of 9 or 10 o'clock.

2. Medium control

Medium control still meant two hands on the wheel, but a maximum of one hand in a High control position. So, for example, one hand could be on the 3 o'clock position, but the other would be on 6 o'clock. An exception was made for two hands in the area between 7 and 5 o'clock, those positions were scored as Low control.

3. Low control

In addition to the 7 and 5 o'clock position mentioned above, driving with only one hand on the wheel was also scored as 'Low control'.

2.5 Self reported measures

The Rating Scale Mental Effort (RSME, Zijlstra, 1993) was used to obtain information about experienced mental workload (effort). Also, after each ride, a risk rating was collected. In this study the original risk questionnaire by Heino (1996) had been adapted to a unidimensional continuous scale. On both scales drivers were asked to rate the manoeuvre of merging into the motorway traffic.

2.6 Performance measures

During the trials driving speed was sampled at a rate of 10 Hz. The mean and standard deviation of the driving speeds were determined while driving on the acceleration lane, and directly after merging into the motorway traffic.

2.7 Design and procedure

Drivers first completed a few rides to get familiar with driving in the simulator. After that all participants completed 10 trials (rides), balanced in order across all participants. Each ride took about 5 minutes. The following factors were manipulated:

- Traffic (three levels; only passenger cars, the present mix of HGV and passenger cars, and a column of HGVs in the slow lane),
- Acceleration lane length (3 levels; normal, extended, and short),
- Presence of a slowly driving lead car (two levels; present or not)

As not all factors could be tested in combination, the selection listed in Table 1 was evaluated. Also, the original experiment contained conditions featuring a driver support system. These conditions were excluded from the present analyses as this system remained silent in most cases (see De Waard et al., 2009).

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Table 1 about here

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Participants started each ride with the car completely stationary. They had to start the engine, follow the lane, and drive along the acceleration lane that joined the motorway. Participants were instructed to join the motorway and that after merging they should, if traffic allowed, move to the fast lane. This instruction was required for another study, in which the potential effects of columns of HGVs on blocking the view of exit signs were evaluated. Driving in the fast lane was neither unnatural nor illegal, as the slow lane was filled with vehicles.

Hand positions were scored at three locations (figure 1):

T1. While speeding up towards the acceleration lane after starting the engine (100 metres after beginning to drive).

T2. Just before merging into the flow of traffic, i.e. directly before leaving the acceleration lane. The last position before using the indicator (to indicate the intended lane change) was scored. This moment was selected to avoid the influence that the use of the indicator could have on hand positions.

T3. After the participant had driven 500 metres in the fast lane of the motorway.

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Insert Figure 1 about here

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To see if hand positions changed during driving, two new parameters reflecting change in hand position were calculated:

change_merge = the change in hand position at T2 compared with T1 (figure 1)

change_to_fastlane = the change in hand position at T3 compared with T2

Change_merge and Change_to_fastlane were calculated per participant and scored as follows:

–2: for a change in hand position from High control to Low control

–1: for a change in hand position from High control to Medium control or for a change in hand position from Medium control to Low control

0: for no change in hand position

+1: for a change in hand position from Medium control to High control or for a change in hand position from Low control to Medium control

+2: for a change in hand position from Low to High control.

After each ride drivers were asked to give a rating of their invested mental effort while they were merging into traffic. They were also asked to indicate on a continuous scale "how risky joining the motorway had been".

As to not to trigger a focus on the hand position, self reports of typical hand positions for different traffic conditions were collected only at the end of the experiment. The questions used were similar to those used by Thomas & Walton (2007) and asked for indications of participant's hand position in low workload traffic conditions, in an average traffic condition, and hand position when tense. Participants were also asked to indicate which hand position is the safest and which hand position gives the most control over the vehicle. Drivers could mark their hand positions on a picture of a steering wheel.

SPSS non-parametric statistical tests were used to evaluate the hand position results. The General Linear Model Repeated Measures test in SPSS was used to evaluate self reports on continuous scales, and speed data. For the analyses the effects of the presence of HGVs (passenger car condition versus mix + HGV Column) and the effects of an increase in HGVs (Mix condition versus HGV Column condition) were considered.

3. Results

3.1 Effect of manoeuvre

No differences in hand position were expected nor found between the seven conditions at T1, directly after driving away after having started the engine (Friedman test, df=6, N=32, χ^2= 8.43, NS). No effect of driving in the fast lane, at T3, was found between the three traffic density conditions (Passenger cars, mix, and HGV column, Friedman test, N=30, df=2, χ^2=1.14, NS). However, at T2, merging into traffic, differences were found (Friedman test, N=33, df=2, χ^2=8.58, p=0.014), but the effect of traffic density is opposite to what was expected. The highest, rather than lowest, proportion of participants were observed to have their hands in the High control position in the passenger cars only condition. In figure 1 the hand positions in the different conditions at T2 are shown.

3.2 Effect of acceleration lane, effect of a slowly driving lead car

There were no effects on hand position of acceleration lane length (Friedman test, N=33, df=2, χ^2=1.17, NS), nor of the slowly driving lead car (Wilcoxon Z=0.000, NS) (Figure 2).

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3.3 Differences between the three sample moments

Differences were found in hand positions between the three sample moments (T1,T2, and T3, figure 3). Hand positions differed between driving away and merging into traffic (T1 vs. T2, Wilcoxon Z= –2.54, p = 0.011), and between merging into traffic (T2) and driving in the fast lane (T3, Wilcoxon Z= –3.10, p=0.002), but not between T1 and T3 (Wilcoxon Z= –0.89, NS). Just before the actual merge manoeuvre more drivers held their hands in the High control position.

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The change_merge and change_to_fastlane parameters were calculated to see if the individual participant's hand positions *changed* during driving, a negative figure reflected a worsening in control positions, a positive figure an improvement in positions, 0 denoted no change. The majority of drivers (about 70%) kept the same hand positions during the three moments that their hand position was sampled, and the more extreme changes of –2 and +2 were not observed. However, from figure 4 it becomes clear that when changes were observed that they were between driving away and merging into traffic (an increase in control), and between merging and driving in the fast lane (decreased control, Wilcoxon Z=–3.25, p = 0.001). In more detail, if the Passenger car condition (Ride A in Table 1), is compared with the mixed traffic (Ride B) and the HGV column conditions (Ride C) 31% of the drivers shift to a "higher control" hand position if a HGV Column is driving next to them on the main road, compared with 18% shifting to these hand position in the passenger car only conditions (see figure 4). However, statistically this effect is not significant (Friedman test, N=32, df=2, χ^2=1.75, NS). When merging is compared with driving in the fast lane the three conditions all show the similar changes in hand positions towards lower control.

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Insert figure 4 about here

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3.4 Group effects

None of the older drivers were ever observed to steer with only one hand while merging into traffic. Whereas 20% of young drivers were observed to have only one hand on the steering wheel while merging. In figure 5 the change in hand positions is depicted per group. As the majority (about 70%) kept the same hand positions, effects are limited and group differences in hand positions do not reach the level of statistical significance. The difference between merging into traffic and driving in the fast left-hand lane can still be seen, with a shift towards higher control when merging, as well as a shift towards lower control once driving in the fast lane.

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Figure 5 about here

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3.5 Speed and self reports

Driving behaviour, in particular speed control (i.e. speed and sd speed), differed between groups and conditions, with the older drivers merging at lower speed than the younger drivers (Hotelling's T = 0.607, $p = 0.001$, , $\eta^2 = 0.38$). The presence of HGVs ($F(1,31)=16.0$, $p < 0.001$, $\eta^2 = 0.34$), and in particular an increase in HGVs ($F(1,31)=18.8$, $p < 0.001$, $\eta^2 = 0.38$), slowed drivers down (figure 6). A slow lead car restricted speed choice and in those conditions a lower driving speed was of course found.

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Figure 6 about here

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Self reported effort, the measure for experienced mental workload, also differed between conditions and groups (figure 7). The older drivers reported less invested effort than the younger drivers ($F(1,31)=6.66$, $p=0.015$, $\eta^2 = 0.18$), and differences between the seven conditions were less pronounced for the older participants. Main effects were found of the presence of HGVs ($F(1,31)=11.95$, $p=0.002$, $\eta^2 = 0.28$) and of an increase in HGVs

($F(1,31)=9.62$, $p=0.004$, $\eta^2 = 0.24$). No effects of acceleration lane length and the slowly driving lead car on reported effort investment were found. Self reported risk (figure 8) shows a similar pattern, with lower scores for the older participants ($F(1,31)=5.08$, $p=0.031$, $\eta^2 = 0.14$), and higher scores for conditions including a HGV ($F(1,31)=9.63$, $p=0.004$, $\eta^2 = 0.24$), but only a non-significant trend effect for the increase in HGVs ($F(1,31)=3.07$, $p=0.089$, $\eta^2 = 0.090$).

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Figure 7 about here

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Figure 8 about here

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3.6 Questionnaire results on hand positions

At the end of the experiment drivers were asked to report their typical hand position in low workload conditions, in average traffic, and when tense. They were also asked what according to them the safest position was, and which position gives most control over the vehicle. Figure 9 summarises their responses.

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Figure 9 about here

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The “safest” and “tense” conditions are very similar, and exclude what has been defined as Low control positions (one hand on the steering wheel). In relaxed and average traffic conditions 20-35% of the drivers indicate one hand on the steering wheel as a common hand position for them.

In Table 2 reported hand positions for the five traffic conditions are listed by age group. Only in the "relaxed" condition was a difference found, with 50% of the older drivers reporting that they hold the steering wheel in the High control position whereas none of the younger drivers indicated this hand position for the "relaxed" condition.

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3.7 Correlations

Average hand positions did not correlate with self-reported effort (r = –0.128, NS) nor with self-reported risk (r = 0.057, NS). The same applies to the change_merge measure (r = –0.149, NS, for effort, and r = –0.003, NS, for risk).

4. Discussion and conclusions

In previous studies Walton & Thomas (2005) and Thomas & Walton (2007) were able to observe a large number of drivers' hand positions on the steering wheel when driving in real life traffic, but they could not observe the whole steering wheel. In the present study fewer but repeated observations of hand positions on the whole steering wheel could be made while drivers performed the demanding task of merging into motorway traffic in a driving simulator. The visibility of the whole steering wheel enabled a wider classification of hand positions into three groups: High control (hands in 9/10 and 2/3 o'clock positions), Medium control (two hands on the wheel but not both in High control positions), and Low control (only one hand on the steering wheel, or two hands between 5 and 7 o'clock).

With regard to the three hypotheses we can conclude the following

H1. Between different moments in a ride and between different conditions hand position is expected to reflect effects of task demands on mental workload; a higher control position is expected in higher mental workload situations.

Only between different moments in a ride did a *change* in hand positions seem to reflect changes in mental workload. The High control position was predominant however.

H2. Between different moments in a ride and between different conditions hand position is expected to reflect perceived risk; a higher control position is expected in higher risk situations.

Again, only between different moments in a ride did a *change* in hand positions seem to reflect changes in reported risk. The High control position is mostly predominant.

It was found that within the participants hand position did not differ very much between different traffic conditions, for example an extended acceleration lane or more or less HGVs on the main road did not coincide with different hand position. The only effect found was opposite to expectations, with a higher percentage of drivers placing their hands in the High control position during the passenger cars only condition. A potential reason for this finding is that in general more than 50% of the drivers hold the steering wheel in a High control position when merging *under all conditions*. This may mean that in this experiment it was difficult to find effects on hand position due to a ceiling effect.

Particularly interesting is the shift in participants hand positions from the moment they drive away to the moment at which they drove on the acceleration lane in order to merge into traffic. A shift in hand position towards higher control while merging into traffic was found and the hand position tended to return to lower control after completion of the manoeuvre. Higher control here means a shift from Low to Medium control, or from Medium to High control, lower control is the opposite effect. Also, when there was a column of HGVs on the main road, relatively more drivers shifted their hands to a higher control position compared with the condition where only passenger cars were present on the main road. It must be said however that this effect did not reach the level of statistical significance, again probably because a very large group (about 70%) of drivers simply did not change their hand positions. Many drivers already held their hands in the High control positions directly after starting the engine and driving away (T1) and kept their hands in these positions until the end of the ride. Therefore these participants could not shift their hands to a higher control position when merging into the flow of traffic. The group of drivers who did not change hand positions in this study is somewhat larger than the percentage of drivers Walton and Thomas (2005) found displaying this behaviour, 70% opposed to 58% of the drivers. One possible explanation is that Walton and Thomas (2005) investigated the change in hand positions at two moments 10 km apart. Their results could therefore be due to unknown changes in task demand between those points, or due to arm fatigue. Walton and Thomas (2005) discount the fatigue explanation by saying that over time just as many drivers moved their hands to a higher position on the steering wheel as lowering them. This is based on the assumption that the High control position can be uncomfortable to maintain for long periods of time. However while other hand positions may not as rapidly produce fatigue as the High control position, keeping your body in any one position for any extended amount of time, especially during a control task, can be fatiguing. Simply moving your hands, even upwards to a potentially more rapidly fatiguing hand position can provide relief. Walton and Thomas (2005) also had no knowledge of how long the drivers they initially recorded for comparison had already been driving with their hands in the position observed.

Also relevant in this context is that one might expect a direct effect of driving speed on hand positions, e.g. higher control positions in high speed conditions. This effect was not found, and statistically significant differences between conditions were absent. Actually over 30% of the drivers moved their hands to High control positions in the lower speed HGV conditions, opposed to less than 20% in the higher speed passenger car condition (see figure 4).

The third hypothesis addressed potential differences between driver age groups.

H3. A larger speed difference with traffic on the main road will occur for older drivers leading to higher mental effort and higher risk, which will be reflected in hand position

A lower speed was found for the older drivers, but this was not accompanied by higher self-reported effort or risk. Nor were differences reflected in hand positions, in fact despite lower perceptions of risk older drivers drove more often with a High control hand position than younger drivers.

Age group differences were most prominent in driving speed with older drivers merging into traffic at slower speed. As stated in the introduction, this may be a compensatory measure. However, this countermeasure, creating more time by slowing down, is not particularly effective when merging into traffic, as the speed difference between their vehicle and speed of traffic on the main road may increase. In addition the expected effect of higher mental effort ratings for older drivers was not found. Rather, older drivers rated both experienced risk and mental effort lower than the younger drivers. The hand positions of the older drivers were, however, always in the Medium or High control positions, while 20% of the younger drivers held the steering wheel with only one hand. This may reflect a habit (see also Table 2) as older participants more frequently reported higher control hand positions for different traffic conditions. However, it might also reflect that the older drivers were very conservative in their self-reported risk and mental effort. It has been found that drivers in general overestimate their driving skills compared with their capability (McKenna, 1993) and older drivers are no exception (Freund et al., 2005). Older drivers additionally also tend to rate their driving ability as better than young people's driving ability (Groeger & Brown, 1989).

Finally there are some additional disadvantages in using observations of hand positions as a measure due to potentially confounding factors that are difficult to completely rule out. For example, use of the indicator will direct the hand to the side of the steering wheel. Automatic gear still is also not very common in Europe, and shifting gear will lead to Low control hand positions. Driver training may also have an effect: in the Netherlands young drivers are now trained to hold the steering wheel in the 9-3 o'clock position to prevent serious injuries if the airbag goes off in case of a collision. In the present experiment the simulator car was equipped with an automatic gear, and hand positions were scored before the indicator was used, but in other conditions this may not always be possible. It is also possible that hand positions on the steering wheel have a relation with personality characteristics. Future studies could shed light on this issue.

In the present study hand positions did not correlate with ratings of perceived risk, as was expected on the basis of the studies by Walton and Thomas (2005) and Thomas and Walton (2007). The usefulness of hand positions as an indicator of experienced risk can thus be questioned. An important limitation of the measure is that many people always hold the steering wheel in the High control position. Therefore the measure may not be sensitive enough to use in short term experimental studies. Also, we consider a relation of hand positions with mental effort more likely than a relation with risk, although ratings of risk and mental effort have been shown to coincide (Lewis-Evans & Rothengatter, 2009). Hand positions did not correlate with self-reported risk or self-reported mental effort, but changes in hand positions seem to coincide with changes in workload demand and control requirements. It is therefore concluded that in combination with information from other measures hand position could give information about mental workload.

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References

Brouwer, W.H. & Ponds, R.W.H.M., 1994. Driving competence in older persons. *Disability and Rehabilitation, 16*, 149-161.

Brundell-Freij, K. & Ericsson, E., 2005. Influence of street characteristics, driver category and car performance on urban driving patterns. *Transportation Research Part D, 10,* 213-229.

De Waard, D., Kruizinga, A., & Brookhuis, K.A. (2008). The consequences of an increase in heavy goods vehicles for passenger car drivers' mental workload and behaviour: A simulator study. *Accident Analysis and Prevention, 40*, 818-828.

De Waard, D., Dijksterhuis, C., & Brookhuis, K.A. (2009). Merging into heavy motorway traffic by young and elderly drivers. *Accident Analysis and Prevention, 41*, 588–597.

Fisher, D., Lee, J.D., Caird, J.K., & Rizzo, M (Eds.) (2009) *Handbook of Driving Simulation for Engineering, Medicine and Psychology*. CRC Press.

Freund, B., Colgrove, L.A., Burke, B.L., & McLeod, R. (2005). Self-rated driving performance among elderly drivers referred for driving evaluation. *Accident Analysis and Prevention, 37*, 613-618.

Fuller, R. (2008). What drives the driver? Surface tensions and hidden consensus. Keynote at the 4th International Conference on Traffic and Transport Psychology, Washington DC, August 31-September 4, 2008.

Fuller, R., McHugh, C., & Pender, S. (2008). Task difficulty and risk in the determination of driver behaviour. *Revue européenne de psychologie appliquée*, *58*, 13-21.

Goldenbeld, C. & Van Schagen, I., (2007). The credibility of speed limits on 80 km/h rural roads: The effects of road and person(ality) characteristics. *Accident Analysis and Prevention*, *39*, 1121–1130

Gray, R.C, Quddus, M.A., & Evans, E. (2008). Injury severity analysis of accidents involving young male drivers in Great Britain. *Journal of Safety Research, 39*, 483–495

Groeger, J.A., & Brown, I.D. (1989). Assessing one's own and others' driving ability: the influences of sex, age and experience. *Accident Analysis and Prevention, 21*, 155-168.

Heino, A. (1996). *Risk taking in car driving; perceptions, individual differences and effects of safety incentives*. PhD thesis. University of Groningen, Groningen, The Netherlands.

Kaptein, N.A. & Claessens, F.M.M. (1998). *Effects of road classification on driving behaviour: a driving simulator study*. (Report TM-98-C048). Soesterberg, the Netherlands: TNO Human Factors Research Institute.

Lewis-Evans, B. & Rothengatter, T. (2009). Task difficulty, risk, effort and comfort in a simulated driving task – Implications for Risk Allostasis Theory. *Accident Analysis and Prevention, 41*, 1053-1063.

Matthews, G., Dorn, L., Hoyes, T.W., Davies, D.R., Glendon, A.I., & Taylor, R.G. (1998) Driver Stress and Performance on a Driving Simulator. *Human Factors, 40*, 136-149.

McKenna, F. P. (1993). It won't happen to me: Unrealistic optimism or illusion of control? *British Journal of Psychology, 84*, 39-50.

Näätänen, R., & Summala, H. (1976). *Road-user behavior and traffic accidents.* Amsterdam: North-Holland.

Reed, P.M. & Green, P.A. (1999) Comparison of driving performance on-road and in a low-cost simulator using a concurrent telephone dialling task. *Ergonomics, 42*, 1015-1037

Summala, H. (2005). Traffic Psychology Theories: towards Understanding Driving Behaviour and Safety Efforts. In G. Underwood (Ed.), *Traffic and Transport Psychology* (First Edition ed., pp. 383-394): Elsevier.

Thomas, J.A. & Walton, D. (2007). Measuring perceived risk: self-reported and actual hand positions of SUV and car drivers. *Transportation Research Part F, 10*, 201-207.

Walton, D. & Thomas, J.A. (2005). Naturalistic observations of driver hand positions. *Transportation Research Part F, 8*, 229-238.

Wilde, G. J. S., (1976), Social interaction patterns in driver behaviour: an introductory review. *Human Factors*, 18, 477-492.

Wood, J.M. (2002). Age and visual impairment decrease driving performance as measured on a closed-road circuit. *Human Factors, 44*, 482-494.

Zijlstra, F.R.H. (1993). *Efficiency in work behavior. A design approach for modern tools*. PhD thesis, Delft University of Technology. Delft, The Netherlands: Delft University Press.

Driver hand position on the steering wheel while filtering into motorway traffic

Dick De Waard, Thigri Van den Bold, & Ben Lewis-Evans

Figure & Table Captions

Figure 1. The three moments (T1, T2, and T3) at which hand positions on the wheel were scored

Figure 2. Hand position just before leaving the acceleration lane (T2, see figure 1) in the seven conditions. HGV=Heavy Goods Vehicle, Acc = Acceleration. Data of both age groups are displayed together

Figure 3: Hand position during the three observed manoeuvres, directly after starting the engine and driving away (T1), during merging into motorway traffic (T2), and after driving 500 metres in the fast lane (T3). Low control is one hand on the steering wheel, high control is two hands in the 9/10 o'clock and 2/3 o'clock positions, medium control is two hands on the steering wheel, but not in the high control positions. Data of both age groups are displayed together.

Figure 4. Change in hand position from start to merging (change_merge), and between merging and driving in the fast lane (change_to_fastlane). Data of both age groups are displayed together

Figure 5. Change in hand position. The majority (70%) kept the same hand positions. -> = compared with.

Figure 6. Speed at T2 in the acceleration lane. HGV=Heavy Goods Vehicle, Acc = Acceleration. Error bars denote Standard Error.

Figure 7. Reported effort during merging into motorway traffic. HGV=Heavy Goods Vehicle,

Acc = Acceleration. Error bars denote Standard Error.

Figure 8. Reported risk (scale 0-100, 100 = maximum risk) during merging into motorway traffic. HGV=Heavy Goods Vehicle, Acc = Acceleration. Error bars denote Standard Error.

Figure 9. Hand position observed while merging into traffic in the HGV column condition, and as reported as typical position after the experiment for five different situations. Data of both age groups are displayed together

Table 1. Seven rides were completed per participant.

Table 2. Self-reported hand positions in five conditions by group

Figure 1
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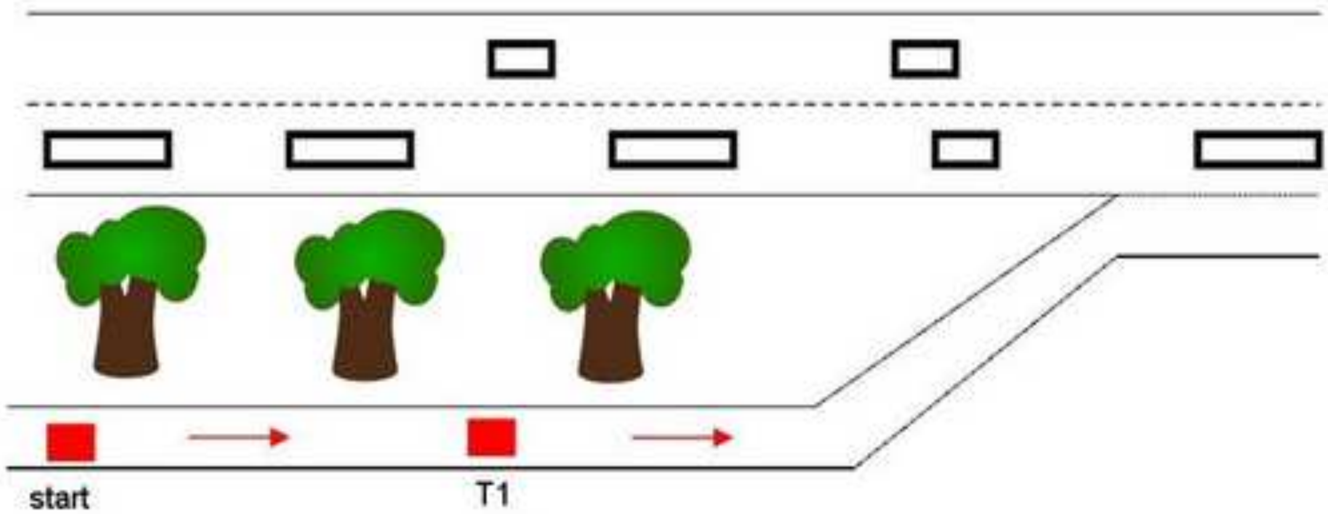
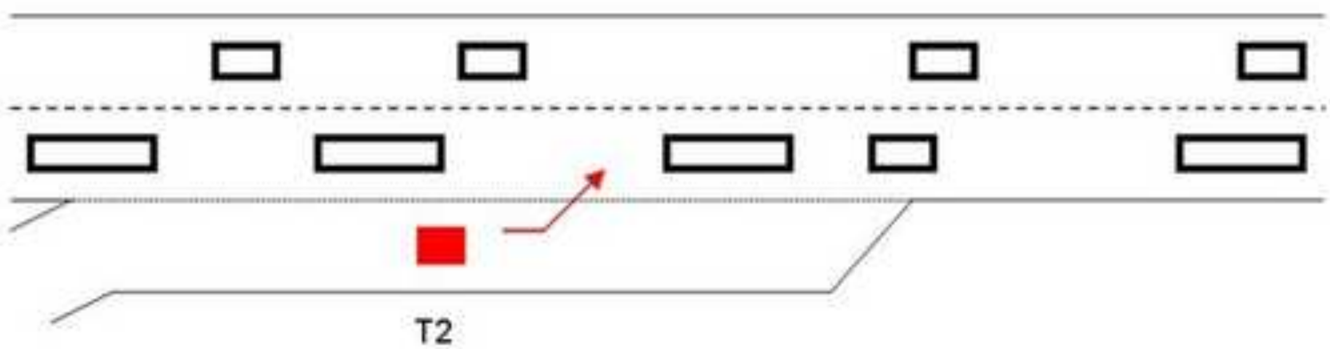
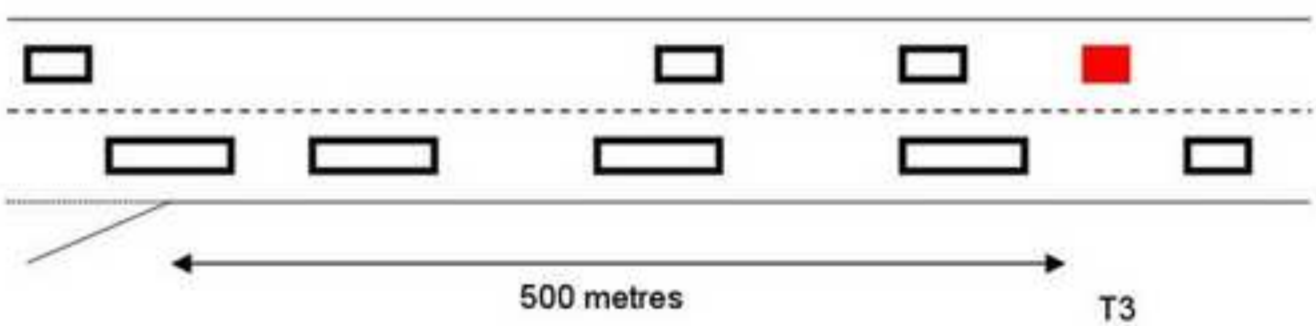


T1, after having driven 100 metres (red square is the participant's car)



T2, before merging into motorway traffic (before operating the indicator)



T3, driving in the fast lane, ½ km after the merge manoeuvre

Figure 2
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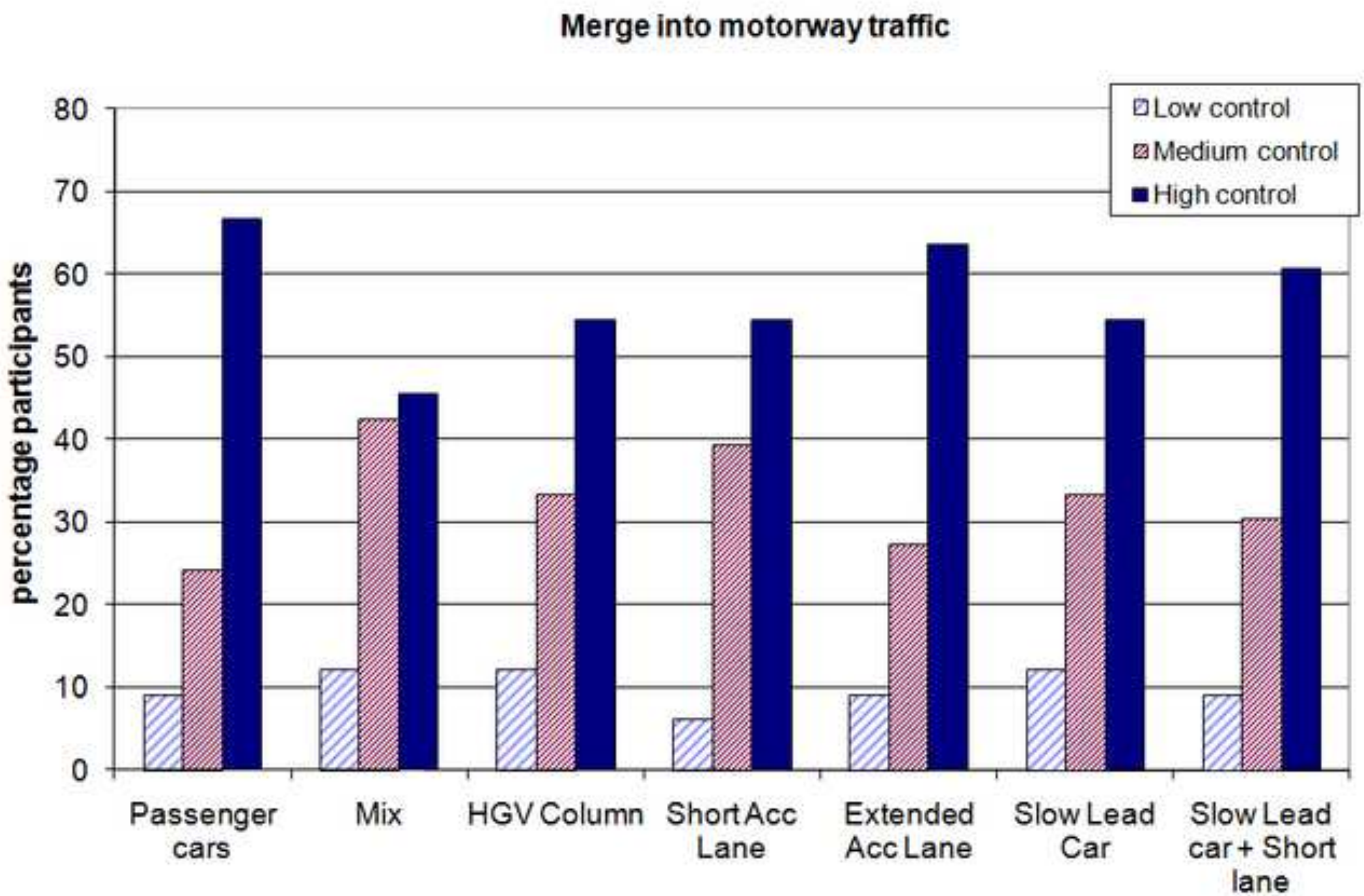

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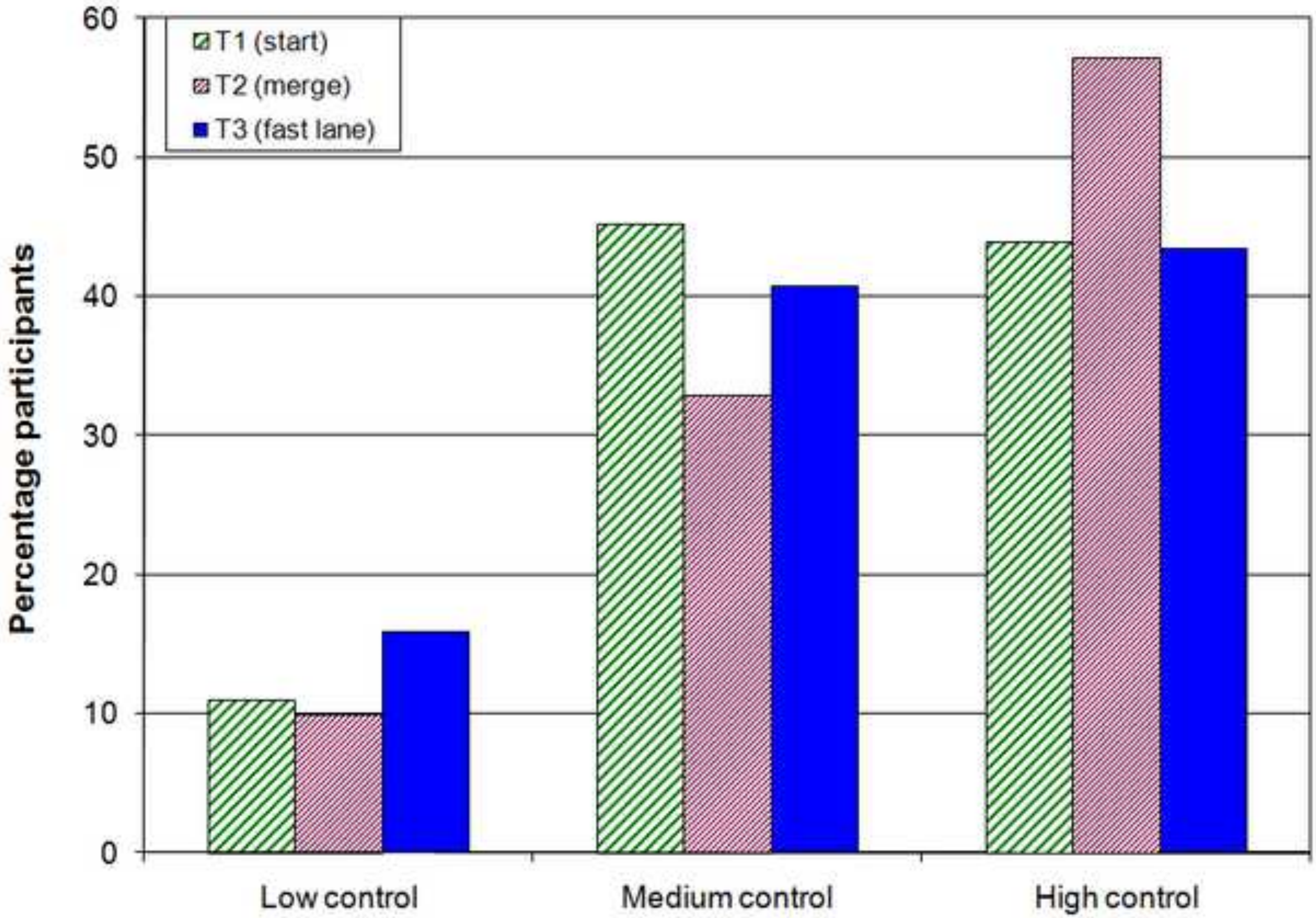

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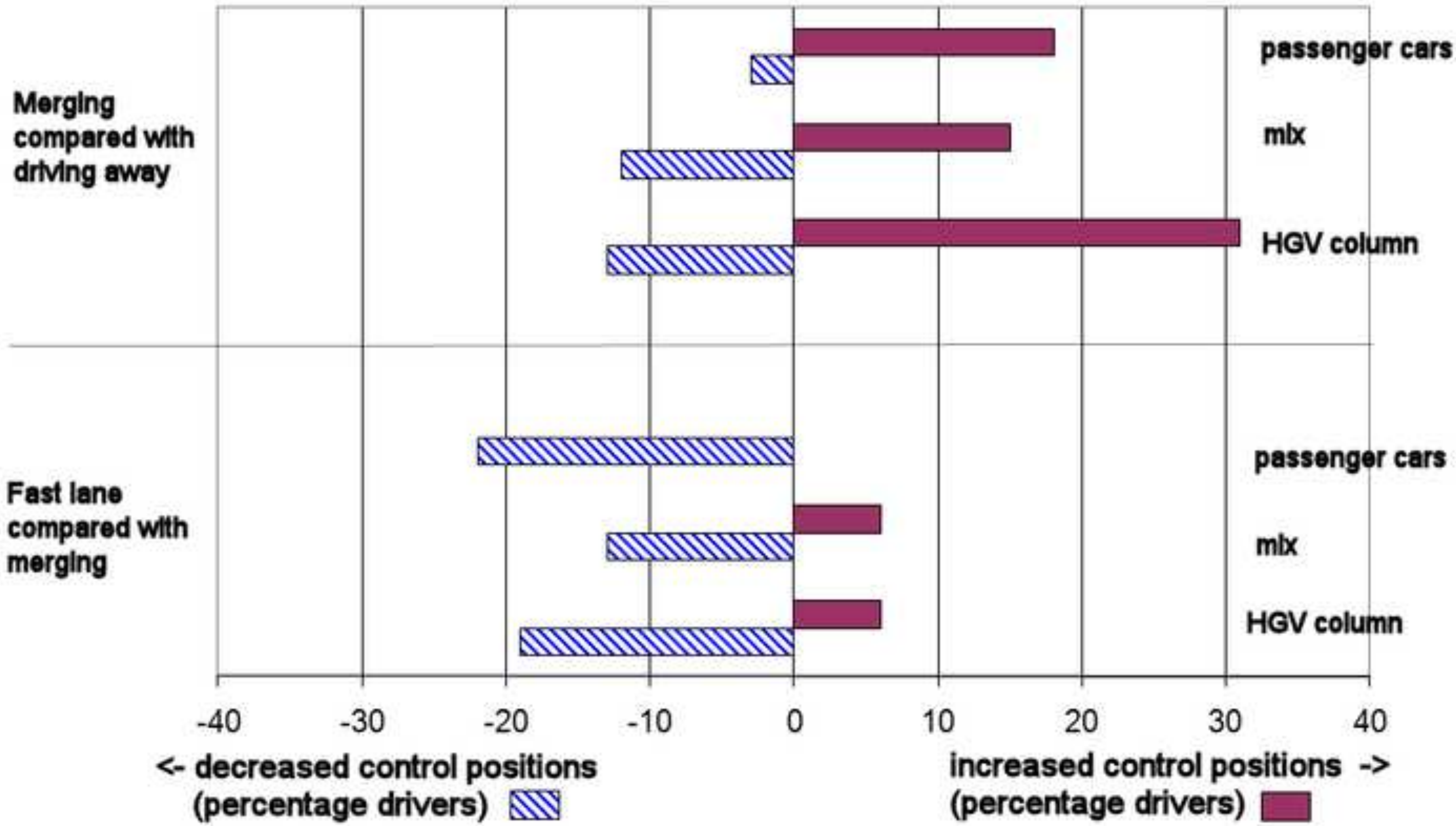

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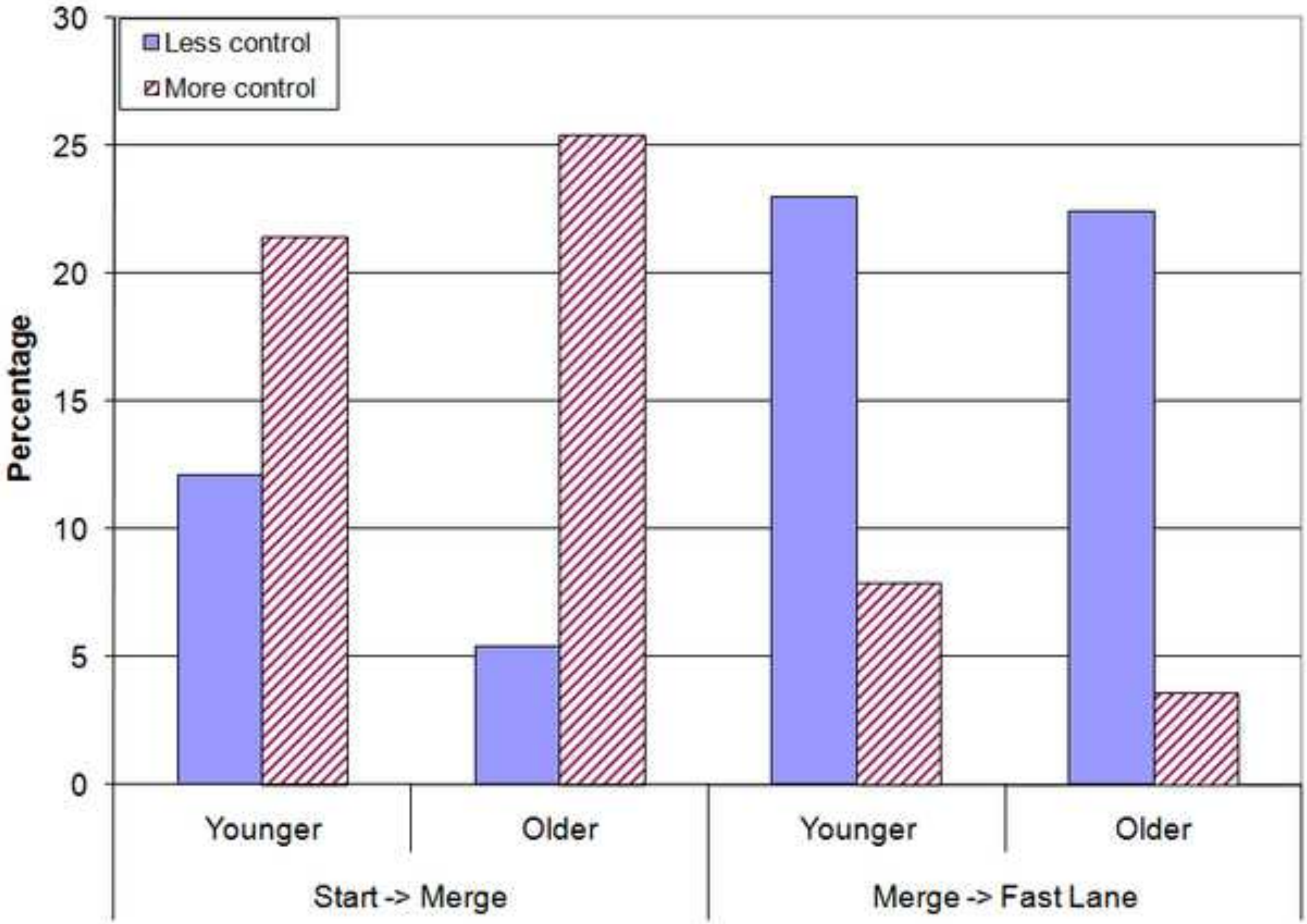

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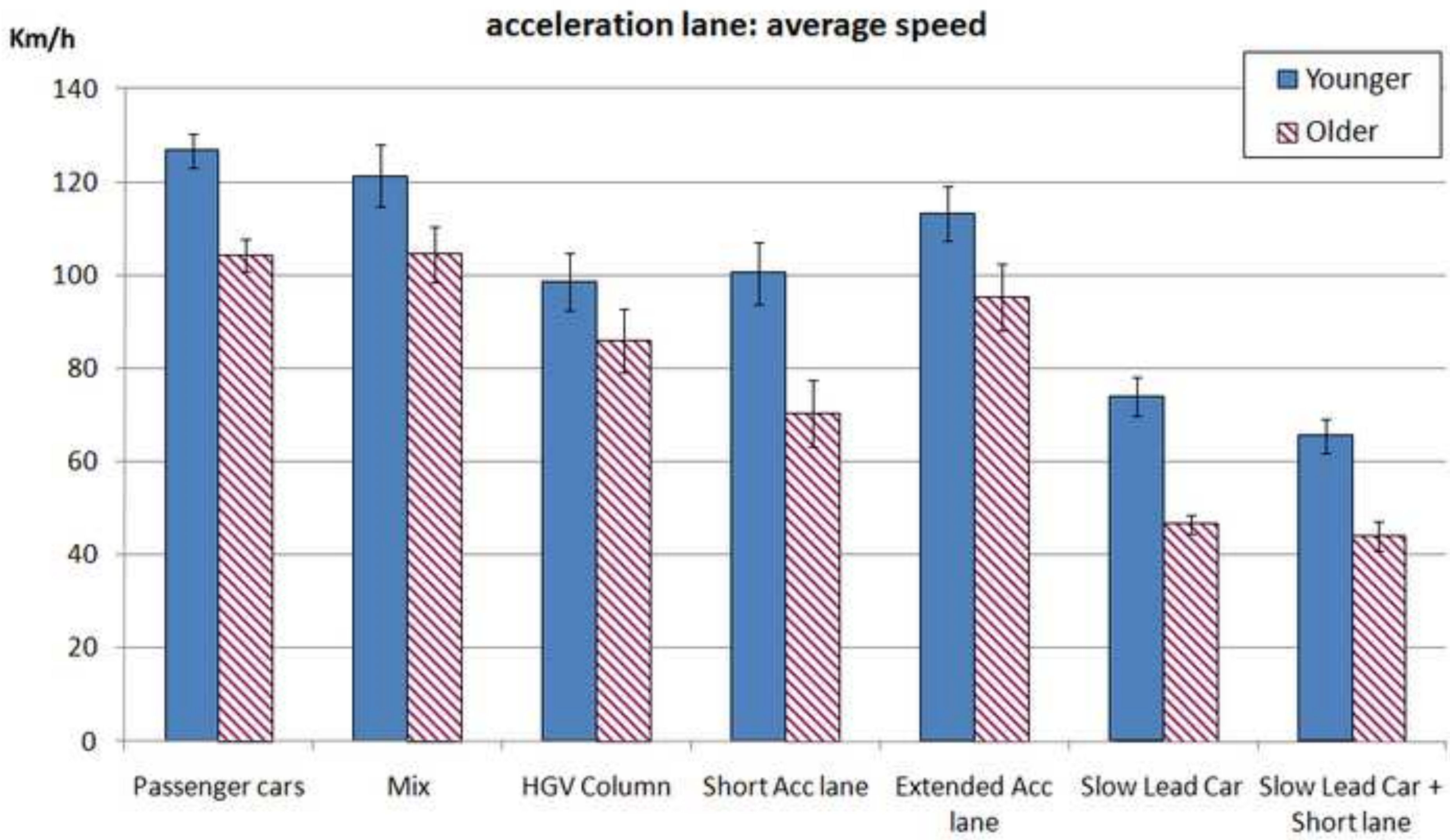

Figure 7
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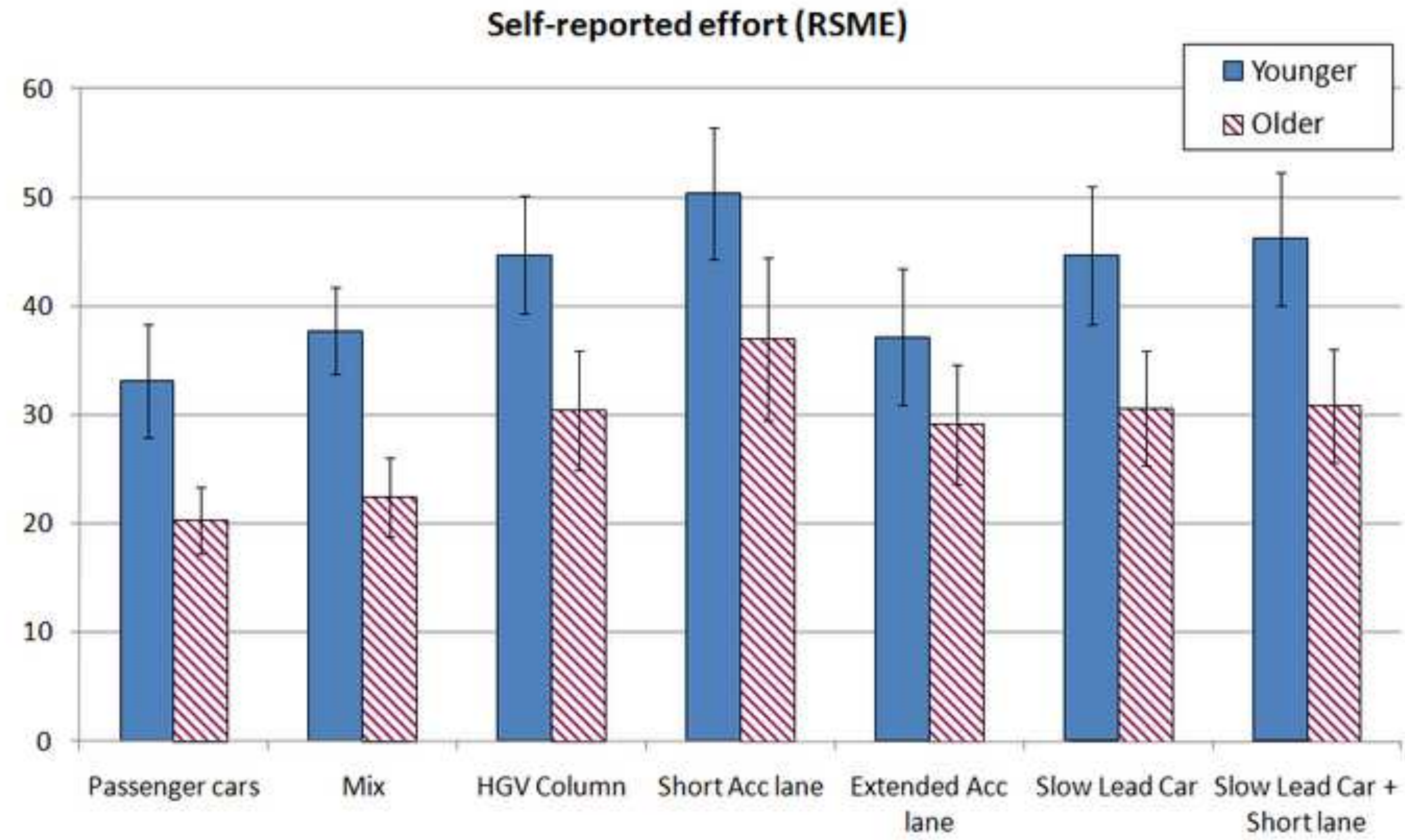

Figure 8
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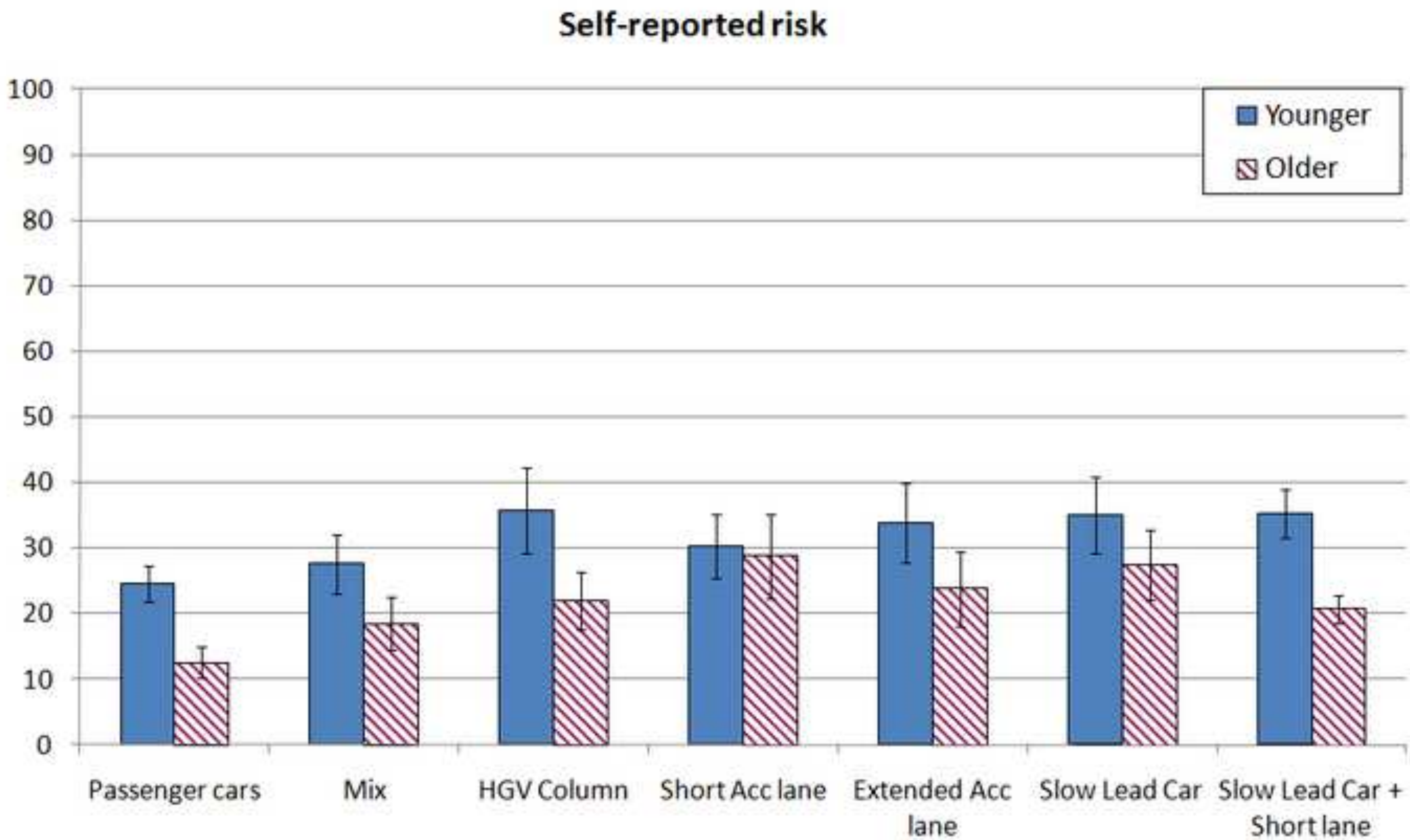

Figure 9
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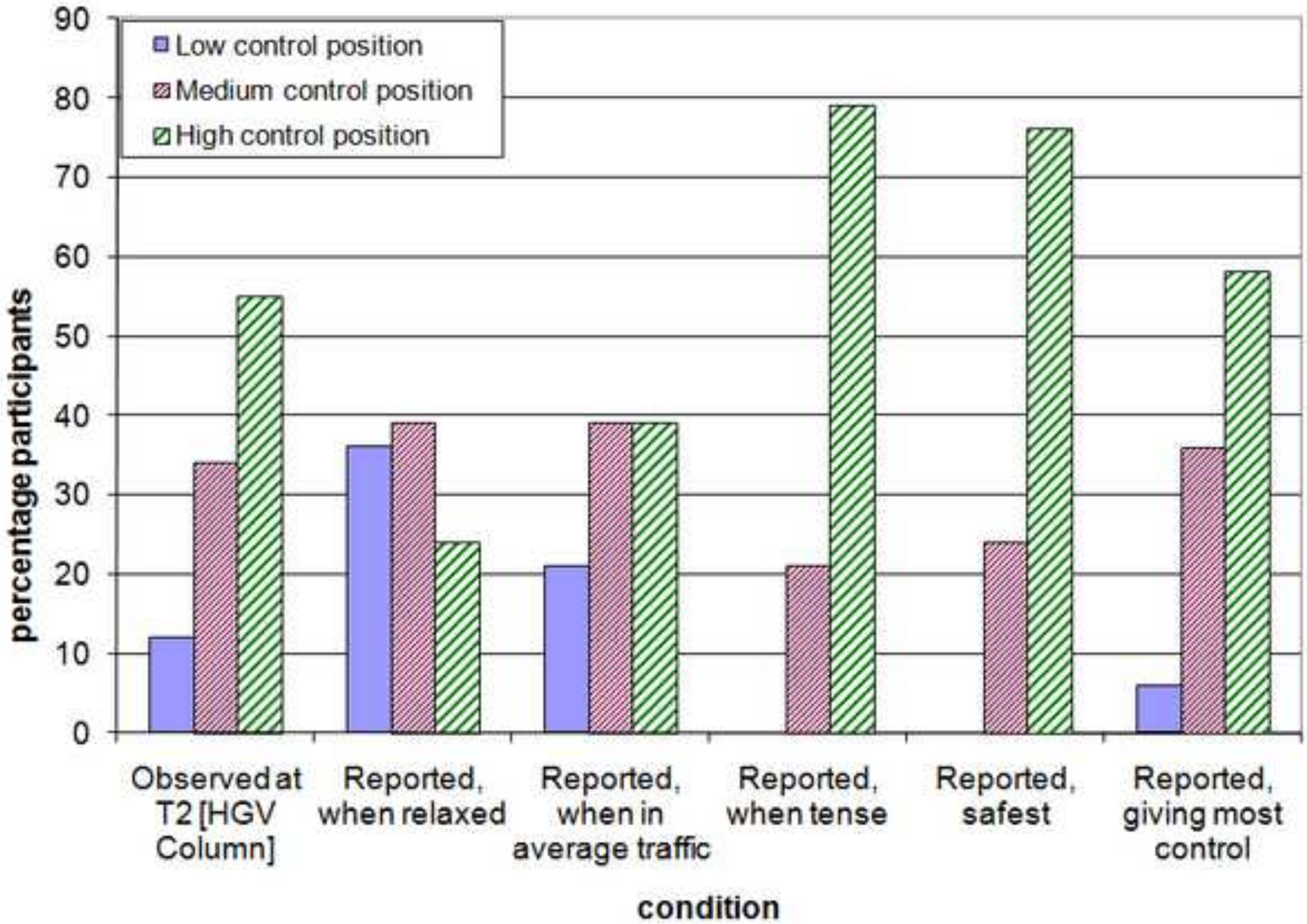

Driver hand position on the steering wheel while merging into motorway traffic

Dick De Waard & Thigri G.M.P.R. Van den Bold

Table 1.

Ride	Traffic	Acceleration lane Length	Cars in the acceleration lane
A	Only passenger cars	300 m Standard	None
B	Mix (“present situation”)	300 m Standard	None
C	HGV Column	300 m Standard	None
D	HGV Column	150 m Short	None
E	HGV Column	450 m Extended	None
F	HGV Column	300 m Standard	in front and behind
G	HGV Column	150 m Short	in front and behind

Table 2.

	Younger			Older			Statistics (Group effect)	signif
	Low control	Medium control	High control	Low control	Medium control	High control		
observed at T2 [HGV Column]	24	29	47	0	38	63	Z= –1.329, NS	
relaxed	47	53	0	25	25	50	Z= –2.54, p = 0.011	*
average traffic	35	35	29	6	44	50	Z= –1.78, p = 0.075	
tense	0	12	88	0	31	69	Z= –1.35, NS	
most safe	0	18	82	0	31	69	Z= –0.90, NS	
most control	12	35	53	0	38	62	Z= –0.78, NS	