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Holding the wheel in passenger cars in countries with driving on the right and left side depending on the driver's side preference

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Abstract. This paper deals with the assessment of the differences in how passenger car drivers hold a steering wheel with left and right-side steering in specific driving modes. The findings are compared to the generally-accepted optimal position in terms of active and passive safety, as well as long-term effects on the health of the driver. The research described in this work was conducted on a sample of randomly selected drivers in the Czech Republic, the UK and Australia using electronic questionnaires. The data was then subjected to a statistical evaluation, which looked primarily at the difference between the way in which the steering wheel was held in countries with driving on the right and driving on the left. Another parameter for statistical data evaluation was the used side preference of individual drivers. On the basis of a statistical evaluation of the obtained data, it was found that there is a difference in the way the steering wheel is held in the assessed traffic situations between drivers driving on the right and drivers driving on the left. The results of this work can be used in the design process of passenger car cabins, in particular in the field of adaptation of the control devices of particular models to the needs of drivers in individual countries based on the type of traffic. The results of the work point out the necessity to make innovations in the design of passenger car cabins with regard to the type of traffic in which the vehicle will be operated, which could lead to a better application of innovations, and thereby better possibilities of positively influencing traffic safety and the health of drivers.

Key words: driver, side preference, posture, hands, steering wheel, left-hand, right-hand, traffic.

INTRODUCTION

The issue of the optimal passenger car ergonomics is currently one of the main components of the construction process of new cars (Wang et al., 2007; Bhise, 2012) and an optimally-designed driver's seat plays a major role herein, particularly in terms of vehicle safety (Reed, 1998). Modern controls, such as multifunction steering wheels, provide a direct link between the driver and the machine, and the optimum design of these elements, combined with the design of various armrests, directly affects the driver's overall comfort and therefore the safety of the vehicle's operation (Chang, 2016).

The position of the driver's hand on the steering wheel is important in a number of respects, but these can often be very contradictory. Firstly, this concerns active safety requirements, a subjective sense of driver comfort, passive safety, and others. There are two groups of people in the human population that can be divided according to their side preference (laterality), or the hand they prefer as their primary hand during work.

Generally speaking, in terms of population representation, the number of people who prefer the left hand, ranges from 10–15% (Healey, 2002). Left-handedness or right-handedness can also be important in the process of driving a car where, for example, right-handed drivers driving a car with the steering wheel on the left are forced to primarily use their left hand, which is not their dominant hand, and vice versa.

The aim of this paper is to find out and assess whether there is a difference in how right-handed drivers and left-handed drivers hold the steering wheel in three basic driving modes. The paper also seeks to ascertain whether there are differences in how the steering wheel is held by drivers driving on the right or left side of the road, again in three basic driving modes.

Some of the findings from previous research are used in the paper that dealt with how drivers driving on the right held the steering wheel, but only in idle mode, which is referred to as situation A (Hruška, 2018) in this paper. As a comparison for the acquired data, the paper uses the values of holding the wheel steering labelled as optimal (Hault-Dubrulle et al., 2010). There is a relatively large consensus among experts on this issue. The most frequently cited optimum value according to the analogue clock face is the position of the left hand on the nine and the right hand on the three, while the driver holds the steering wheel with both hands (Schiro et al., 2013, Hault-Dubrulle et al., 2010). This value is considered optimal regardless of the location of the steering wheel in the vehicle.

A whole range of research deals with measurement of how passenger car drivers hold the steering wheel (Schmidt et al., 2015) and is usually focused on the impact of grip on passive safety and the subsequent type and extent of injury during an accident. Mostly, however, these are individual measurements of a small number of test persons in laboratory conditions and on special measuring stools (Schiro et al., 2013). Adversely, this paper collects data from a large group of drivers moving in a real environment so that it can be used to evaluate the results of the statistical method.

The primary objective of this paper is to assess the hypothesis that there is a statistically significant difference in the way the steering wheel is held by drivers driving in the right and by drivers driving on the left. The secondary objective of this paper is to assess the hypothesis that there is a statistically significant difference in how left-handed drivers and right-handed drivers hold the steering wheel. These measurements will be carried out in three different traffic situations in order to assess a broader range of activities that drivers perform under real conditions.

In some published studies dealing with ergonomics (Hruška & Jindra, 2016), it was found that there is a correlation between the driver's gender and his or her ability to control the vehicle and to adapt its controls. As part of the primary and secondary objectives of this paper, gender of the respondent was also used as a parameter to supplement the finding of dependency.

MATERIALS AND METHODS

Participants

A total of 160 participants (82 women and 78 men) were obtained from the Czech Republic, Great Britain and Australia, who were divided into two groups of 80 respondents. Each group of respondents comes from countries with road traffic driving on a different side. Respondents from the Czech Republic were included in the group of

drivers who drive on the right (Table 1), and respondents from the UK and Australia were included in a group of drivers who drive on the left (Table 2). The age of all participants ranged from 19 to 65 years (the average age was 33.7 years). All of the participants were given the clear condition that they must have a driver's license authorizing them to drive passenger cars. All of the participants of the survey were also strongly advised that they must be in good health and have no restrictions on their movement apparatus, which could distort the results.

Table 1. Data about test persons from the group of drivers driving on the right (CZ)

Gender	Number	Age			Side preference	
		Average	Minimum	Maximum	Right-handed drivers	Left-handed drivers
Men	40	29.7	20	52	27	11
Women	40	32.2	19	64	34	8
Total	80	30.9	19	64	61	19

Table 2. Data about test persons from the group of drivers driving on the left (UK, AUS)

Gender	Number	Age			Side preference	
		Average	Minimum	Maximum	Right-handed drivers	Left-handed drivers
Men	38	38.4	21	65	27	11
Women	42	34.7	20	56	34	8
Total	80	36.5	20	65	61	19

Tested traffic situations

Three basic traffic situations were defined for research purposes in which the interviewed drivers could find themselves and answer how they most often hold the steering wheel in the given situation. These consist of three common situations in which drivers repeatedly find themselves on the road. Each of these situations has been thoroughly verbally described and supplemented with an illustrative photo for better understanding. **Situation A** was described as highway or high speed traffic at low traffic when the driver is not subjected to psychological pressure. **Situation B** was described as driving outside the city on a secondary road with more turns, in medium traffic, when the driver is subjected to medium-intensity psychological pressure. **Situation C** was described as driving outside the city with reduced visibility and very dense traffic, with very high demands on the driver and the driver being subjected to considerable psychological pressure.

Data Collection Procedures

Basic data collection was carried out with the help of electronic questionnaires in two language versions. Their translations and semantically-identical content were verified by a professional translation agency. As part of the basic information provided in the questionnaire, respondents were advised to devote sufficient time to filling out individual questions and had schemes available to help them better imagine the situation (Fig. 1). Although the questionnaire method may not be as accurate as real-environment testing, given the set objectives and the number of subjects surveyed, testing in a real environment would be virtually impossible in organizational terms.

The questionnaire consisted of nine questions divided into two groups. The first group were questions about age (in years), gender (female, male), and side preference (right-handed, left-handed). In addition, for the period for which he or she had a driver's licence (in years), the test subject was interviewed about how often he or she drove a passenger car (every day, at least once a week, occasionally, exceptionally), with the final data being about the position in which the subject most often sits behind the steering wheel (a choice of three basic positions divided according to the subject's chest distance from the centre of the steering wheel).

In the second group of questions, the test subject was asked to gradually imagine each of the three traffic situations described above and responsibly state for each of them whether he or she held the steering wheel with one or both hands, and in which position. This was always based on the pre-selected scheme attached to each question (Fig. 1), where, according to the watch face, the range of R12-R6 was defined for the right hand, and for the left hand the analogous range of L6-L12. The overlap at 12 and 6 o'clock is selected because the test groups from left and right handed traffic were evaluated. The subject was also told to indicate the most prevalent value of the grip on the steering wheel. We dismissed extreme values, where the test subject crosses the hand and held steering wheel with, for example, the left-hand on the right, as highly unlikely in view of the objectively high degree of discomfort the driver would experience in such a position. For this reason, we completely discarded these variations.

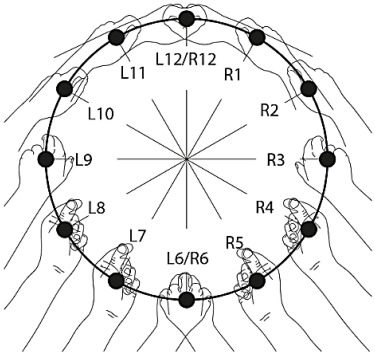

Figure 1. Scheme of positions of individual grips according to an analogue watch face.

RESULTS AND DISCUSSION

The results obtained during the measurements were statistically processed and evaluated using contingency tables, Pearson's chi-squared test and adjusted residuals methods. The percentage representation of individual hand positions on the steering wheel (regardless of whether the steering wheel is held by one hand or both) obtained from the measured data are shown in Table 3 for respondents driving on the right, and in Table 4 for drivers driving on the left.

It can be seen from the data presented in Table 3 and Table 4 that there are some differences in the positions in which the steering wheel is held by drivers driving on the right and drivers driving on the left. It is also very clear that no matter what type of traffic they are in (Table 5 and Table 6), drivers hold the steering wheel more often with both hands if the traffic situation is more complex (situation B and C). These differences are explained below based on the dependence of holding the steering wheel on the laterality of the test subjects and on the type of traffic in which they are moving.

Table 3. Percentual representation of grips for drivers driving on the right (CZ)

Item	Situation A			Situation B			Situation C		
	Total (%)	Men (%)	Women (%)	Total (%)	Men (%)	Women (%)	Total (%)	Men (%)	Women (%)
L6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
L7	8.3	8.8	7.9	2.7	0.0	5.3	0.0	0.0	0.0
L8	9.7	8.8	10.5	5.3	2.7	7.9	1.3	0.0	2.5
L9	31.9	35.3	28.9	22.7	24.3	21.1	25.0	32.5	17.5
L10	40.3	35.3	44.7	58.7	56.8	60.5	68.8	60.0	77.5
L11	5.6	8.8	2.6	5.3	8.1	2.6	3.8	5.0	2.5
L12	4.2	2.9	5.3	5.3	8.1	2.6	1.3	2.5	0.0
∑ L	100	100	100	100	100	100	100	100	100
R12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R1	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	2.6
R2	36.2	38.1	34.6	55.9	50.0	61.1	64.0	54.1	73.7
R3	25.5	28.6	23.1	30.9	37.5	25.0	30.7	40.5	21.1
R4	21.3	19.0	23.1	11.8	12.5	11.1	2.7	2.7	2.6
R5	10.6	9.5	11.5	1.5	0.0	2.8	1.3	2.7	0.0
R6	6.4	4.8	7.7	0.0	0.0	0.0	0.0	0.0	0.0
∑ R	100	100	100	100	100	100	100	100	100

Note: The percent values are calculated separately for the right and left hand and the values in this table do not take into account whether the driver holds the steering wheel with one hand or both.

Table 4. Percentual representation of grips for drivers driving on the left (UK, AUS)

Item	Situation A			Situation B			Situation C		
	Total (%)	Men (%)	Women (%)	Total (%)	Men (%)	Women (%)	Total (%)	Men (%)	Women (%)
L6	1.6	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
L7	4.8	3.4	6.1	0.0	0.0	0.0	0.0	0.0	0.0
L8	35.5	37.9	33.3	26.0	24.2	27.5	12.8	16.2	9.8
L9	17.7	20.7	15.2	26.0	27.3	25.0	29.5	27.0	31.7
L10	38.7	31.0	45.5	45.2	45.5	45.0	56.4	56.8	56.1
L11	1.6	3.4	0.0	2.7	3.0	2.5	1.3	0.0	2.4
L12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
∑ L	100	100	100	100	100	100	100	100	100
R12	1.6	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R1	1.6	3.7	0.0	6.5	0.0	7.5	2.5	2.6	2.4
R2	35.5	25.9	42.9	49.4	50.0	60.0	52.5	50.0	54.8
R3	30.6	40.7	22.9	22.1	37.5	15.0	26.3	23.7	28.6
R4	19.4	18.5	20.0	18.2	12.5	10.0	13.8	21.1	7.1
R5	11.3	7.4	14.3	3.9	0.0	7.5	5.0	2.6	7.1
R6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
∑ R	100	100	100	100	100	100	100	100	100

Note: The percent values are calculated separately for the right and left hand and the values in this table do not take into account whether the driver holds the steering wheel with one hand or both.

Also interesting are the differences between holding the steering wheel with one or both hands, depending on whether the respondents are men or women, as can be clearly seen in Table 5 and Table 6. It is evident that women use both hands more often than men regardless of the current traffic situation. This finding has already been published

in some earlier surveys, which can be confirmed by this finding (Hruška, 2018). This assertion is also confirmed by statistical evaluation (Table 7). The explanation for these differences can be seen both in the anthropometric parameters of men and women (Tilley 2002, Wang et al., 2007), but also at the psychological level, where women tend to approach driving more responsibly (Bergdahl, 2005) and try to observe the generally recommended position of L9R3 at the cost of lower subjective comfort.

Table 5. Representation of drivers driving on the right (CZ) according to how they hold the steering wheel

Holding the steering wheel	Situation A			Situation B			Situation C		
	Total (%)	Men (%)	Women (%)	Total (%)	Men (%)	Women (%)	Total (%)	Men (%)	Women (%)
Left hand	41.2	47.5	35.0	15.0	20.0	10.0	5.0	7.5	2.5
Right hand	10.0	15.0	5.0	6.2	7.5	5.0	0.0	0.0	0.0
Both hands	48.8	37.5	60.0	78.8	72.5	85.0	95.0	92.5	97.5

Table 6. Representation of drivers driving on the left (UK, AUS), according to how they hold the steering wheel

Holding the steering wheel	Situation A			Situation B			Situation C		
	Total (%)	Men (%)	Women (%)	Total (%)	Men (%)	Women (%)	Total (%)	Men (%)	Women (%)
Left hand	22.5	28.9	16.7	3.8	2.6	4.8	0.0	0.0	0.0
Right hand	22.5	23.7	21.4	8.8	13.2	4.8	2.5	2.6	2.4
Both hands	55.0	47.4	61.9	87.5	84.2	90.5	97.5	97.4	97.6

The claim that whether a driver holds the steering wheel with one or both hands depends on gender can only be statistically confirmed in situation A. Dependency was not demonstrated in situations B and C, which can be interpreted in that if the traffic situation is more complex and the driver may perceive it as potentially more dangerous, both men and women use both hands to drive more often. This trend is evident for all drivers regardless of whether they are driving on the left or on the right (Table 7).

Table 7. Results of the statistical evaluation of dependency of holding the steering wheel on the gender of the driver

Dependency	Degrees of freedom	X^2	Critical value	Cramer's V	Significance level	Level of dependency
Situation A	1	5.58	3.84	0.186	0.05	medium
Situation B	1	2.62	3.84	0.464	0.05	none
Situation C	1	0.80	3.84	0.071	0.05	none

Based on the data shown in Table 8, it is clear that if the driver holds the steering wheel with only one hand, there is a difference between which hand right-handed drivers use for holding the steering wheel, and which hand left-handed drivers use. This difference is statistically very significant for drivers who drive on the left (UK, AUS). For drivers driving on the right, this dependence is not as obvious.

This is mainly due to the fact that drivers driving on the right have the steering wheel on their left in their cars and are therefore indirectly forced to use their left hand as their primary hand if they are driving with only one hand. In this case, the right hand

is more often used to shift and control secondary and tertiary vehicle control systems that are located in the centre of the vehicle. In this case, therefore, all left-handed drivers use their preferred hand as the primary hand for controlling the vehicle and this group is statistically unrecognizable. For drivers who drive on the left and have the steering wheel in their vehicle on the right side, their primary hand for driving the vehicle is their right hand. Drivers whose preferred hand is their left hand primarily use their left hand when driving at the cost of possible subjective discomfort in a statistically significant number of cases, as shown in Table 8.

Table 8. Results of the statistical evaluation of dependency of according to the set hypotheses for situation A

Group of respondents	Drives with the left hand	Drives with the right hand	Drives with both hands	∑
Left-handed (UK,(AUS)	17 (+++)	1 (0)	1 (---)	19
Right-handed (UK, AUS)	1 (---)	17 (++)	43 (+++)	61
Left-handed (CZ)	7 (0)	0 (0)	6 (0)	13
Right-handed (CZ)	26 (0)	8 (0)	33 (0)	67
∑	51	26	83	160

Note: In the Table 8, a sign scheme is used, that expresses the standard deviation rate from the expected value; (+++) – the result very significantly exceeds the expected frequency at the significance level of 99.9; (++) – the result significantly exceeds the expected frequency at significance level 99; (+) – the result exceeds the expected frequency at significance level 95. (0) – the value does not differ significantly from the expected frequency; (-) – the result does not reach the expected frequency at significance level 95; (--) – the result does not significantly reach the expected frequency at significance level 99; (---) – the result does not very significantly reach the expected frequency at significance level 99.9.

When comparing the data between a group of drivers who drive on the left (UK, AUS) and the group of drivers driving on the right (CZ), a certain imbalance was found in the number of drivers who drive with both hands in situation A. This finding was investigated via further personal interviews on a narrower sample of respondents, and the most likely explanation is that drivers in the UK and Australia behave slightly more responsibly than drivers in the Czech Republic.

In order to confirm the goals and hypotheses defined above, it was necessary to subject the measured results to a statistical analysis. In order to test the dependency of holding the steering wheel on the other above mentioned parameters, the previously mentioned Pearson's chi-square dependency test was used, supplemented by the method of adjusted residuals.

In Pivot Table 8, complex input data are displayed in order to evaluate the statistical significance of holding the steering wheel depending on the laterality of the tested persons driving on the right or on the left. The PivotTable (Table 8) has six degrees of freedom and distinguishes holding with the right or left hand, or both. Table 9 lists the dependency rates for the three basic combinations.

In order to evaluate the dependency of the method of holding the steering wheel on side-type traffic, the value X^2 (8.56) was calculated, which is higher than the critical value (5.99), which confirms the primary initial hypothesis that the method of holding the steering wheel depends on the side-type traffic. The dependency rate was further verified by Cramer's V (0.231) at a significance level of 0.05 and, based on the calculated values, the dependency of the method of holding the steering wheel on side-type traffic can be labelled as medium.

Table 9. Results of the statistical evaluation of dependency according to the set hypotheses

Dependency	Degrees of freedom	X^2	Critical value	Cramer's V	Significance level	Level of dependency
Method of holding the steering wheel in side-based traffic	2	8.56	5.99	0.231	0.05	medium
Method of holding the steering wheel on the side of the driver	2	34.51	5.99	0.464	0.05	strong
Method of holding the steering wheel on the type of traffic and on the side of the driver	6	61.81	12.59	0.439	0.05	strong

In order to evaluate the dependency of the method of holding the steering wheel on the side of the driver, the value X^2 (34.51) was calculated, which is higher than the critical value (5.99), which confirms the primary initial hypothesis that the method of holding the steering wheel depends on the side of the driver. The dependency rate was further verified by Cramer's V (0.464) at a significance level of 0.05 and, based on the calculated values, the dependency of the method of holding the steering wheel on the side of the driver can be labelled as strong.

If both dependencies are evaluated together, in order to evaluate the dependency of the method of holding the steering wheel on the side of the driver and on the side-type traffic, the value X^2 (61.81) was calculated, which is higher than the critical value (12.59), which confirms the primary initial hypothesis that the method of holding the steering wheel depends on the side of the driver and on the side-type traffic. The dependency rate was further verified by Cramer's V (0.439) at a significance level of 0.05 and, based on the calculated values, this combined dependency can be labelled as strong.

When assessing the measured data, it becomes clear that any subject who does not hold the steering wheel with both hands in a lateral synchronous position will necessarily be subject to a certain degree of rotation of the upper half of the body, the rate of which will vary depending on the particular position in which the steering wheel is held. If we assess the occupational health aspects of holding the steering wheel as described above on the health of the driver, it should be noted that the worst positions for gripping the steering wheel are L11, L12, R12 and R1.

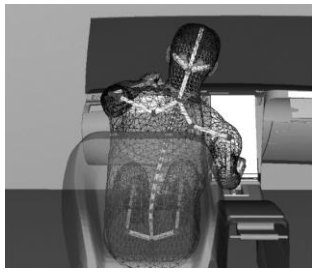

Figure 2. Driver holding the steering wheel in position L12.

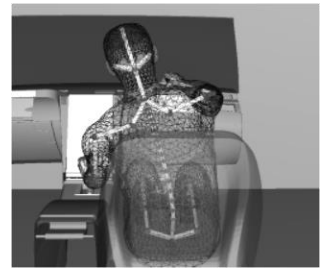

Figure 3. Driver holding the steering wheel in position R12.

The Tecnomatix Jack program was used to simply evaluate these positions, in which the L12 (Fig. 2) position for drivers with steering on the left and the R12 position

(Fig. 3) for drivers with steering on the right. Both simulations were performed using a 95-percentile man in a middle-class common sedan. In Figs 2 and 3, it is quite clear that the driver holding the steering wheel only with the left hand in the least suitable L12 position, or with the right hand in position R12, leads to significant lateroflexion with significant muscle strain, in particular *m. quadratus lumborum, m. obliquus externus abdominis, m. obliquus internus abdominis a m. erector spinae.* Long-term driving in such a position can lead to pain in the lumbar spine and, in the extreme, to permanent damage to the postural system (Véle, 1995, Havlíčková, 1999).

In this paper, we were able to obtain a large amount of valuable primary data from a large group of respondents from three different countries with road traffic on two sides of the road, which may be interesting in terms of possible comparisons with other statistics that could be obtained from respondents with other parameters, or from other countries. By analysing the data using contingency tables, it was found that a statistically significant group of respondents hold the steering wheel in a manner that cannot be labelled as optimal on the basis of the selected comparison parameters, regardless of whether the driver is driving on the left or on the right.

This finding could be used for the further development of passenger car cabins, whereby modelling of the interior could create conditions in which the driver of the vehicle would not be forced to find a subjectively comfortable grip on the steering wheel, but which, for the above reasons, cannot be described as optimal (Hault-Dubrulle et al., 2010; Schiro et al., 2013). This would eliminate the human factor, which is imperfect in these cases of subjective assessment.

On the basis of the above results, it can be further stated that the primary hypothesis mentioned in the introduction of the thesis has been fully confirmed. There are statistically significant differences in how a driver holds the steering wheel in countries where traffic moves on the right side of the road and in countries where traffic is on the left. This can be explained by the simple structural difference in the arrangement of the vehicle cabin with the steering wheel located on the right or on the left. It was also found that in both types of traffic there are statistically significant differences between how both men and women hold the steering wheel. The explanation of this phenomenon can be found in the generally more responsible approach of women to driving a car (Vágnerová, 2007), but also in the fact that as opposed to women, men are able to better relax in a vehicle and instinctively keep a more relaxed position (Wilson, 2001; Bergdahl, 2005).

We were also able to prove the secondary hypotheses presented in the introduction to this paper, and it can be confirmed that there is a statistically significant difference in how drivers preferring to use their left or right hands hold the steering wheel. This dependency was more strongly confirmed for drivers driving on the left.

The above hypotheses were tested in three theoretical traffic situations, but the above hypotheses have been demonstrated to be statistically significant only in situation A, which was defined as a calm ride along a highway or motorway in light traffic outside of the city. Dependency was not confirmed in situations B and C, which were defined as more complicated in terms of traffic and drivers could perceive them as more dangerous. This can also be assessed in that the more complex the situation, the more the driver tends to hold the steering wheel with both hands, regardless of gender, laterality or the side that the traffic is on.

CONCLUSIONS

The results presented in this paper could serve as a basis for further research to further refine the above findings. The data and hypotheses presented in this paper could serve as ancillary factors in the design of cars with respect to potential target customers.

The contribution of this paper can also be seen in the number of subjects tested and the involvement of the gender factor. Another benefit of this paper is the provision of valid data for further follow-up research, in which the above results could be refined or supplemented by data obtained from field studies in other countries.

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